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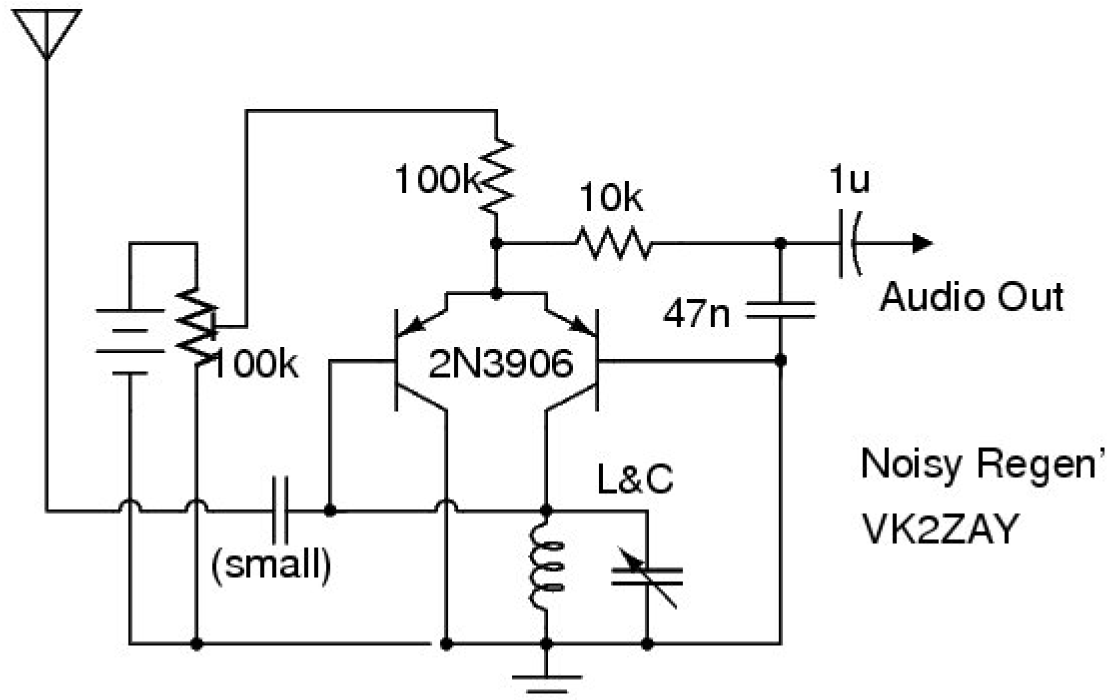
Home Twitter YouTube Calculators

The "Noisy Regen"

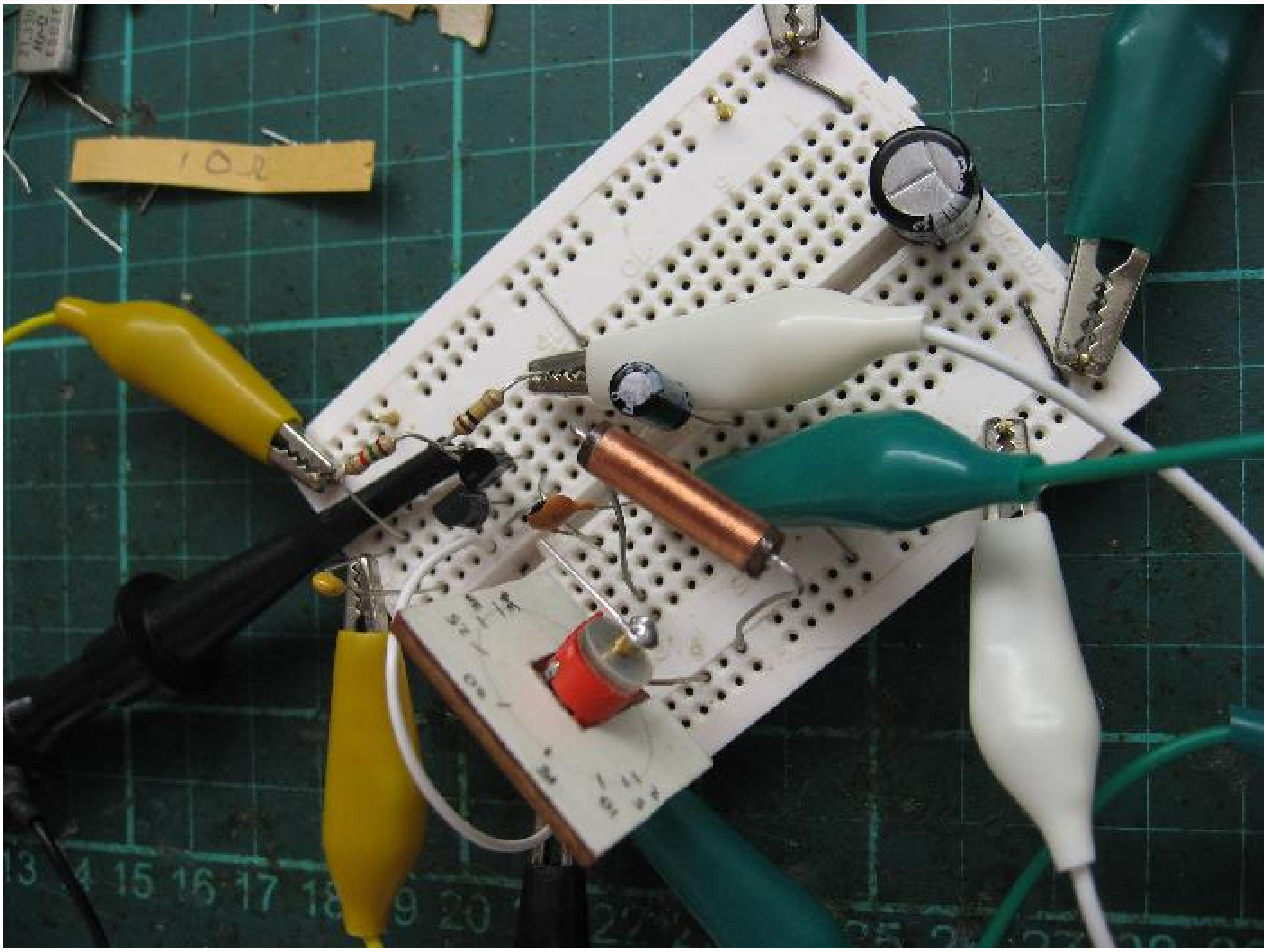
2007-07-17

This circuit is essentially the same topology as the "noisy oscillator" in EMRFD (page 4.13, diagram 4.21). I've just used PNP transistors (2N3906) so I can "ground" the tuning capacitor rotor and still use a "conventional" -ve potential ground plane (making it easier to integrate with common-grounded test equipment).

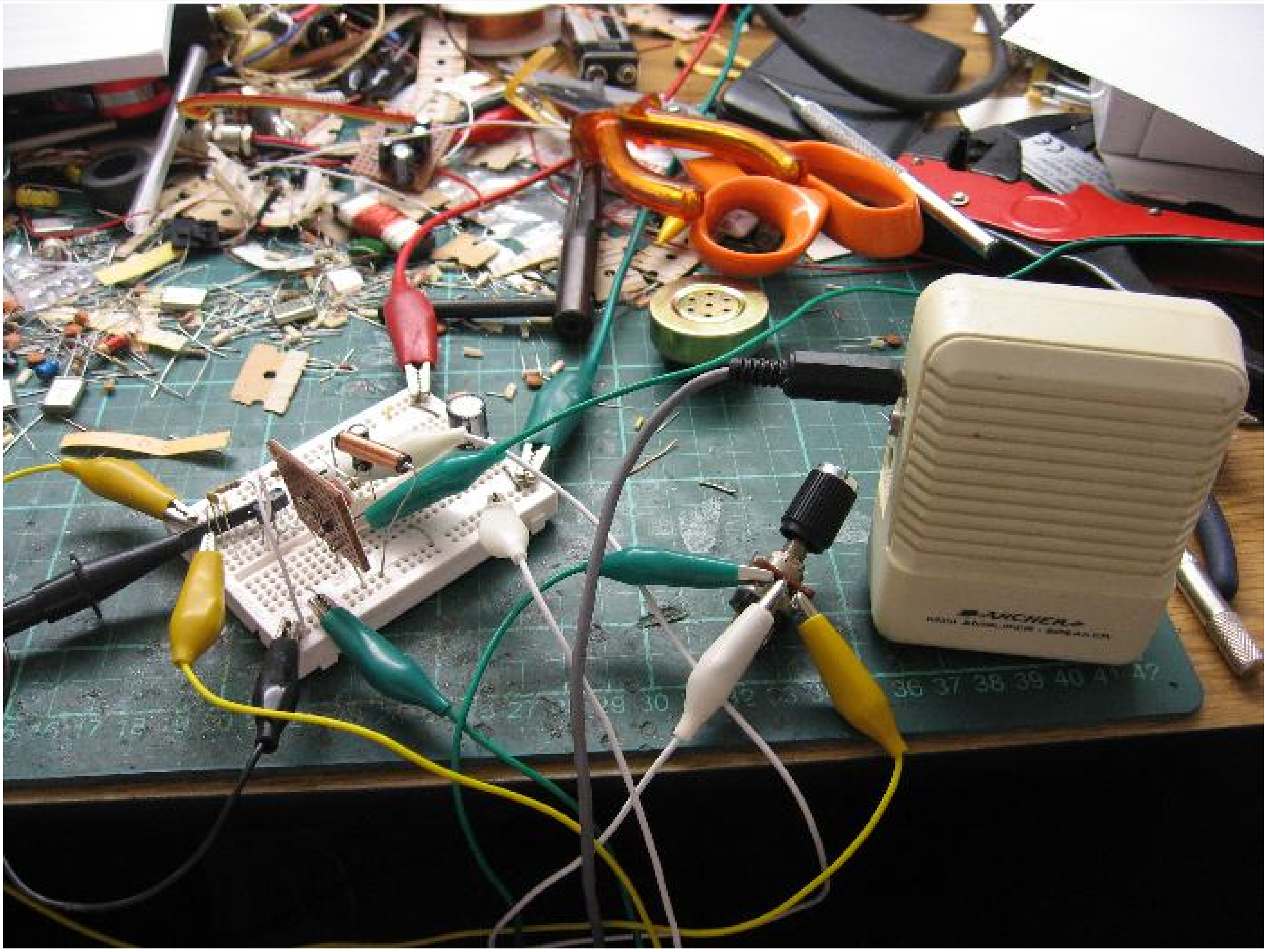


Although running at a very low current (which gives the transistors a reasonably high Re) the tight coupling of the resonator with the transistors severely degrades its Q, especially as the regeneration is turned up high. It actually performs fairly well when the reaction coefficient is just less than 1, but once the -ve resistance is increased until it oscillates is becomes one of the noisest oscillators I've ever seen. Even when just regenerating it is pretty noisy and broad.

OK, so it sucks electrically, but it does have some utility. It is extremely easy to get going, virtually any inductor that isn't completely hopeless will work in the circuit. It pulls very, very little current and works from LF to VHF. It needs only just over a volt to oscillate on the lower bands, and 3 volts will work into the low VHF region. The only frequency determining components are the L and the C, although the transistor capacitances are very significantly coupled to the resonator, limiting its MUF and complicating estimating the appropriate values for a particular frequency - two seconds of empirical capacitor swapping will get you in the right ballpark. The regeneration control modulates the transistor capacitances as well, pulling the frequency a bit, but this isn't unusual for a regenerative receiver and the selectivity is so bad anyway it doesn't matter much above MF.



About 2 minutes after I assembled it on the solderless breadboard I was listening to Radio Australia on 6.025 MHz with just a short clip lead for an antenna (coupled directly to the tank at the collector though a 2.2 pF cap - the tank itself was simply a 10 uH Ohmite RFC and my low-C jig). It truly is an instant gratification receiver, and can be used with a crystal earpiece resulting in a circuit that pulls less than 300 uA, meaning no off-switch is required for a pair of AA batteries. I added a stage of audio amplification, using an 2N3904 with the familiar self-biasing (1M feedback, 4k7 collector load). Even without this, the circuit can drive the old Archer "Mini Amplified Speaker" Tandy used to sell, but the extra gain is helpful for weaker stations.



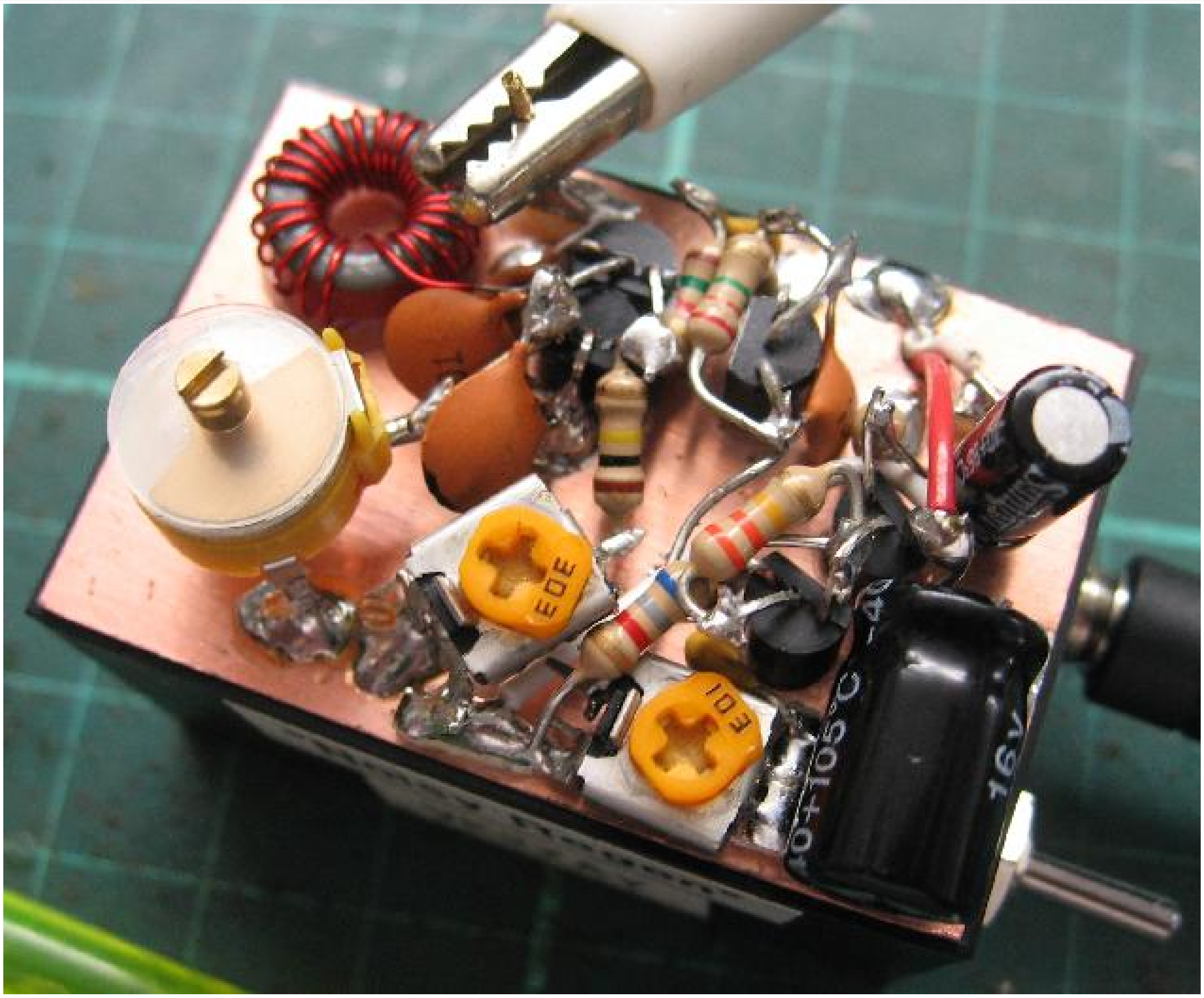
Other Uses

The circuit can be setup to super-regenerate by changing the emitter circuit to contain an RFC and a capacitance across the emitter resistor. In this mode it seems the circuit would be an excellent telemetry or control receiver; micropower, sensitive, and not too tuning critical. It would be fairly easy to integrate this circuit with a microcontroller for remote-control use. My surplus of 27.195 MHz crystals suggests some direction for future experiments with this topology.

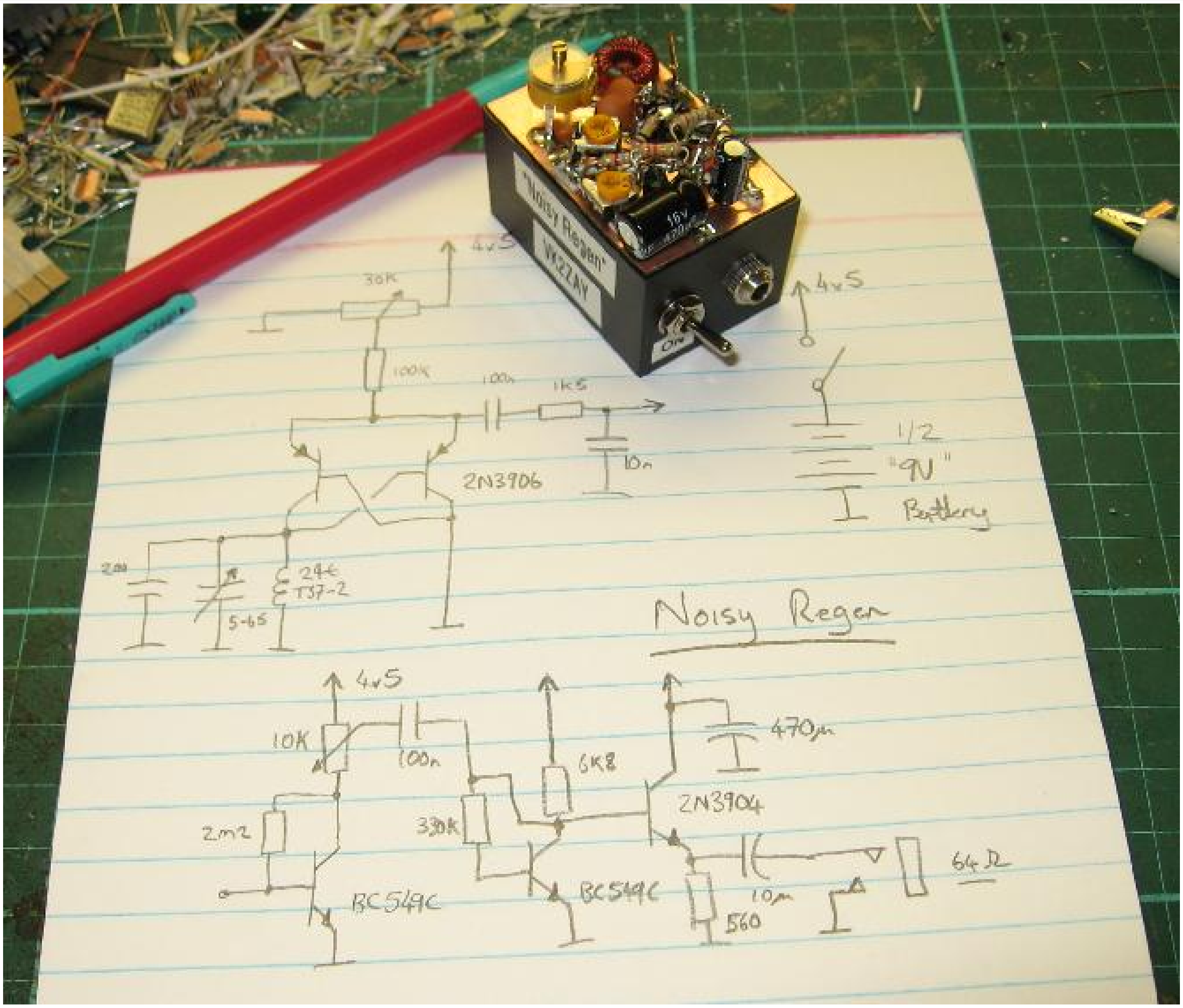
Another use might be a LF receiver for a lightning detector. Many moons ago I built a version of Charles' lightning detector (a great little project, build one, they are fun). One thing that bugs me about it though is the need for an antenna. I think this little cross-coupled regen circuit would be perfect (being micropower) to build a lightning detector with a loopstick magnetic antenna rather than an electric whip.

Building a more Permanent Version

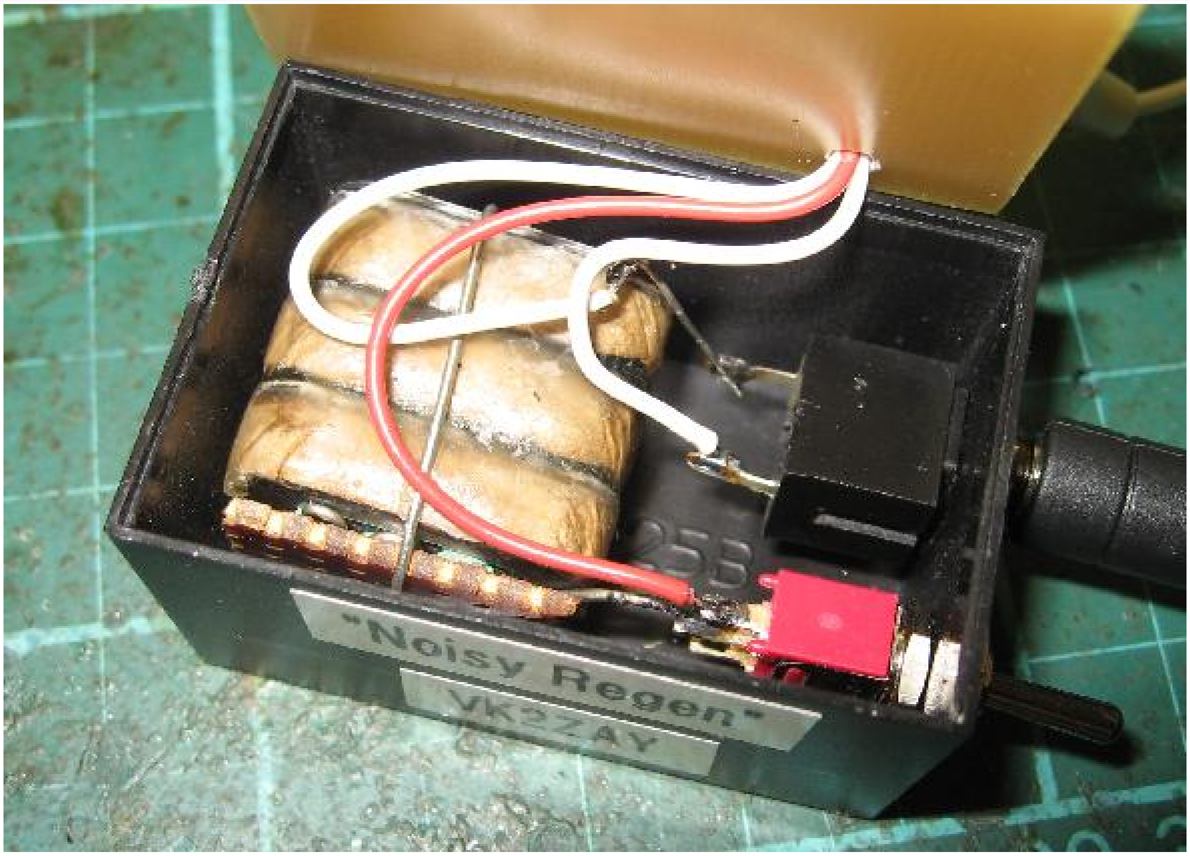
The "Noisy Regen" might not be much of a radio, but I couldn't help myself, I just had to give it a permanent place amongst my homebrew receivers. The circuit was rebuilt on PCB, this time with a 65 pF trimmer for tuning and a toroidal inductor wound on a T37-2 core (an additional 200 pF of fixed inductance was needed to put the receiver on the 49 metre band - this gives you a good idea of just how much the transistor capacitance is coupled to the tank, the inductor measures around 2.3 uH, which means it must see an additional 50+ pF of capacitance elsewhere to resonate near 6 MHz with the mid-trimmer capacitance).



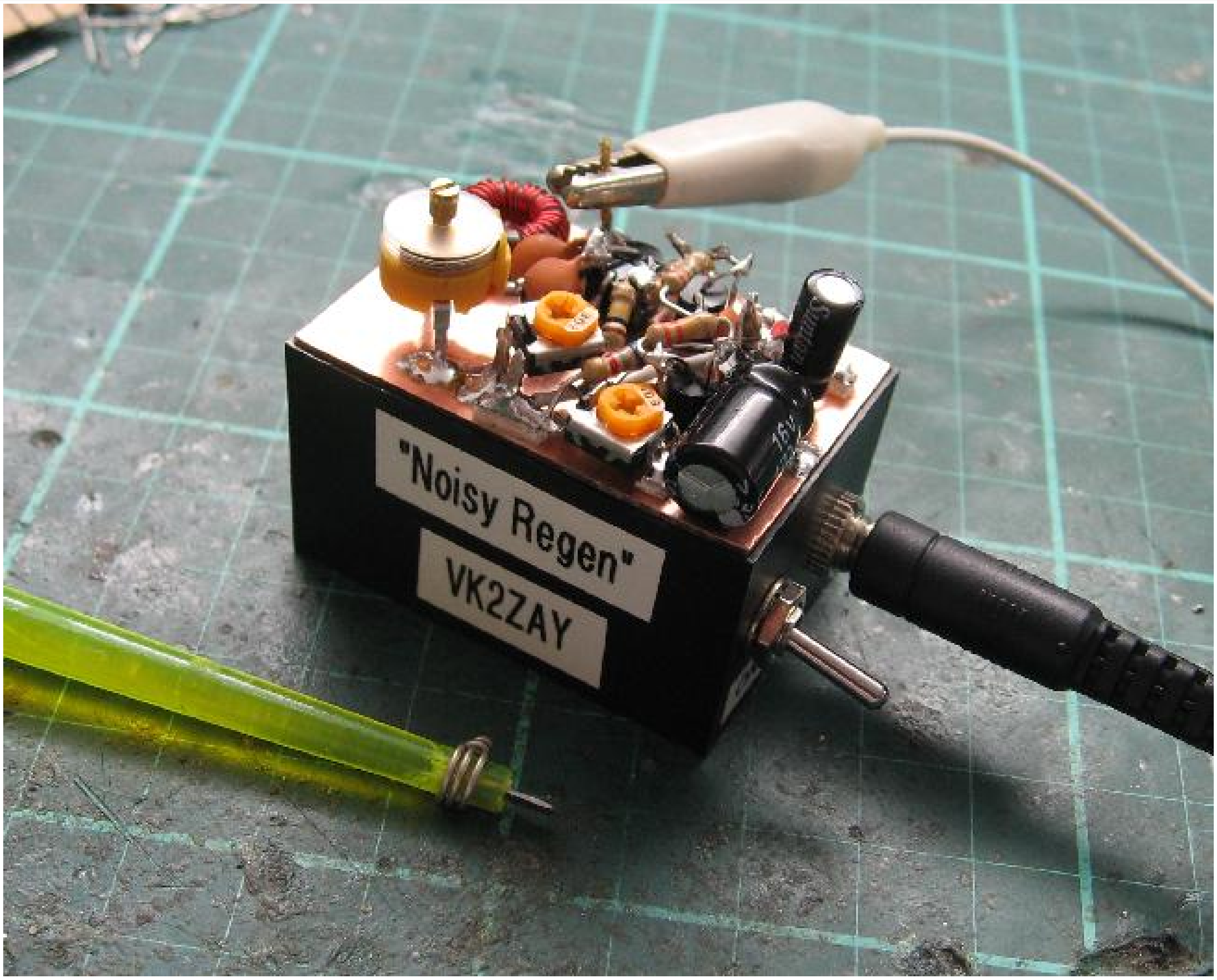
A simple three transistor audio amplifier was thrown together to drive 32 Ohm headphones. Complete the radio pulls about 3.5 mA and delivers enough audio for comfortable listening at home. (Omitted from this diagram is a 1 nF capacitor across the 2M2 feedback resistor in the first amplifier, this rolls off the AF response and kills the HF noise.)



The PCB was cut and filed down to be a perfect friction fit in the top of a Jaycar potting case. The case itself houses half a 9V battery, the power switch and a stereo 3.5 mm headphone socket. To create the battery I dismantled a cheap 9V unit and snapped the wax-potted cell stack in half. (Some batteries have 6 sub-AAA cells instead of a linear stack of "pellet" cells, but even sub-AAA cells were too large to fit comfortably in the case.) This gives a 4.5 volt battery of moderate internal resistance. Actually the higher source resistance meant I had to raise the decoupling cap in the audio amplifier to 470 uF to prevent howling at max gain. My general purpose bench supply and AA batteries did not need this much capacitance for stability. A 10 nF cap from the emitter follower base to ground might help a little too, but I'm happy with the final result.



The antenna connection is simply a PC pin, which a clip lead is connected to, leading to a random wire for quite reasonable reception of the stronger stations. The radio tunes approximately 5.8-6.7 MHz which covers all of 49 metres, but it might be helpful to pull it a little lower to spread out the channels a little.



The little unit is quite cute. It is not a huge performer as receivers go, and you have to adjust it with a screwdriver, but it was a nice project none the less. This weekend it let me listen to Saturday Night Country on Radio Australia, but I also heard Radio New Zealand and a bunch of other stations. Sure, I can use any number of other radios I have, some with the comfort of AGC and other features, but there is nothing quite like using a radio you designed and built yourself, even one as backward and hacky as this one.

Suggested Improvements

- Add a 220-1K resistor and large (at least 10 uF) capacitor before the 10K volume control pot. This will stop AF noise on the power supply rail getting into the AF amplifier and causing howling at minimum volume with bad layouts and/or weak batteries.
- Adding a similar decoupling network to the intermediate BC549 and the detector stage can't hurt either if you are having stability problems.
- Consider building something less primitive than the emitter follower audio output stage!
- Add band-switching. (41 and 31 metres would be nice too)
- Build it bigger! (Although its small size is a large part of its charm)

Update: 2007-08-25

I use this little radio quite a lot, so much that I've flattened the battery three times now. The process of replacing the battery has grown tiresome; it involves hacking open a particular brand of 9 Volt battery and fixing up the anode contact with some care. I decided to install an external power jack (mono 3.5 mm socket) and run with conventional AA batteries in a 4-cell holder.

The "complete" radio isn't a self-contained 2 cubic inches any more, but I still get great joy out of using it.

7 comments.

Attachments

Circuit Source	application/postscript	14.563 kbytes

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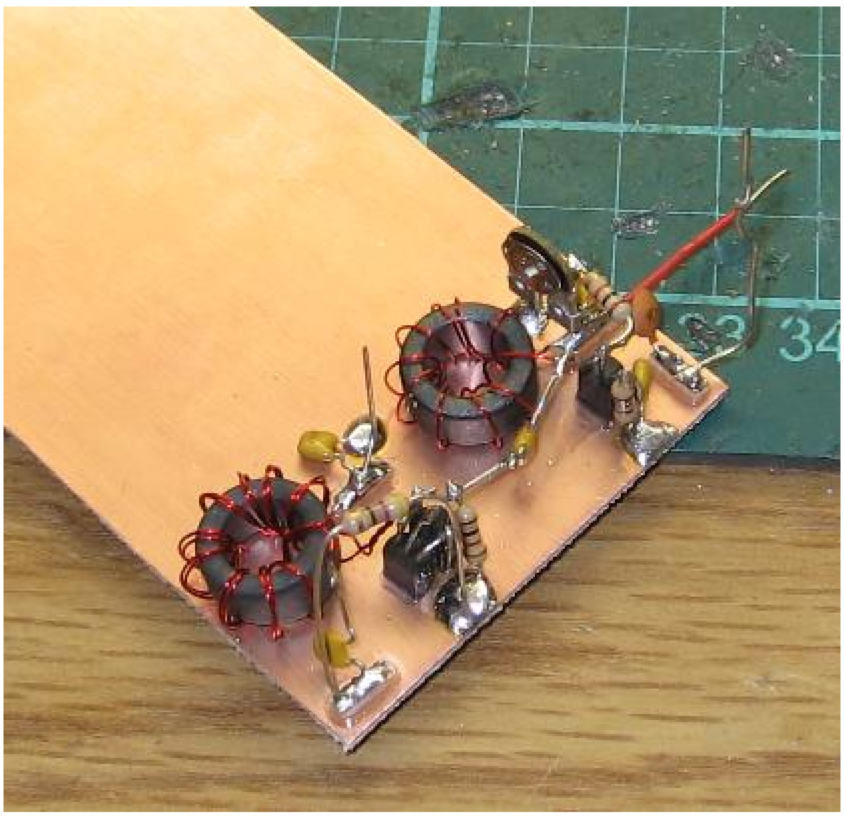
The "Wee Willy" RF Power Amp

2007-01-22

I first saw the Dick Pattinson VE7GC Wee Willy on the "Popcorn" site. It is quite an interesting little rig, but some things about the design concerned me, so until now I've largely ignored it. In particular, the final power amplifier stage is essentially class-C which seemed unlikely to work well for a DSB signal. The Solder Smoke guys were talking about it in an episode I heard on the way home from work tonight (21 I believe), so I decided to build and test it out. The circuit is so simple, I figured I could whack it together before dinner - which indeed I did, took less than 2 hours to build and customise the device.

I did not have VN10KM devices, but they are /fairly/ similar to 2N7000 devices, so I built it with 2N7000 devices instead. The VN10KM has slightly worse properties in most ways, except its dissipation capability, which is somewhat better, I suspect due to the metal tab most versions have embedded in the TO-92 case.



If you do the math on the output network at a 6 V supply you'd expect gain compression around 500-600 mW out. I *really* doubted the claims of 1 W out at 6 V. At 12 V it is definitely possible to get 1.5 W or more out, but the efficiency at either voltage will be pretty bad due to the modest on-resistance of the devices.

The driver stage is clearly designed for high-Z in and out, at 50 Ohms its power gain is only about 12 dB. My completed amplifier gave 25 dB more or less flat to 18 MHz (without the LPF network). Gain drops to about 23 dB at 1 MHz because of the transformers, and the gain is still usable at 30 MHz (about 20 dB). The 2N7000 has quite low capacitances, it is practical to build a HF-flat amplifier that puts out about 2 Watt with them paired up in push-pull.

Built as specified in the Wee Willy there is a noticeable "threshold" effect from the unbiased output stage. I assume either the noise or carrier leakage from earlier circuits make this a minor problem in the actual Wee Willy. Either that, or the VN10KMs have much lower threshold voltages. To avoid this problem with my amplifier I added another pot to bias the output stage as well.

Best efficiency is achieved with about 10 mA on the driver and 25 mA on the final pair. Efficiency isn't that good

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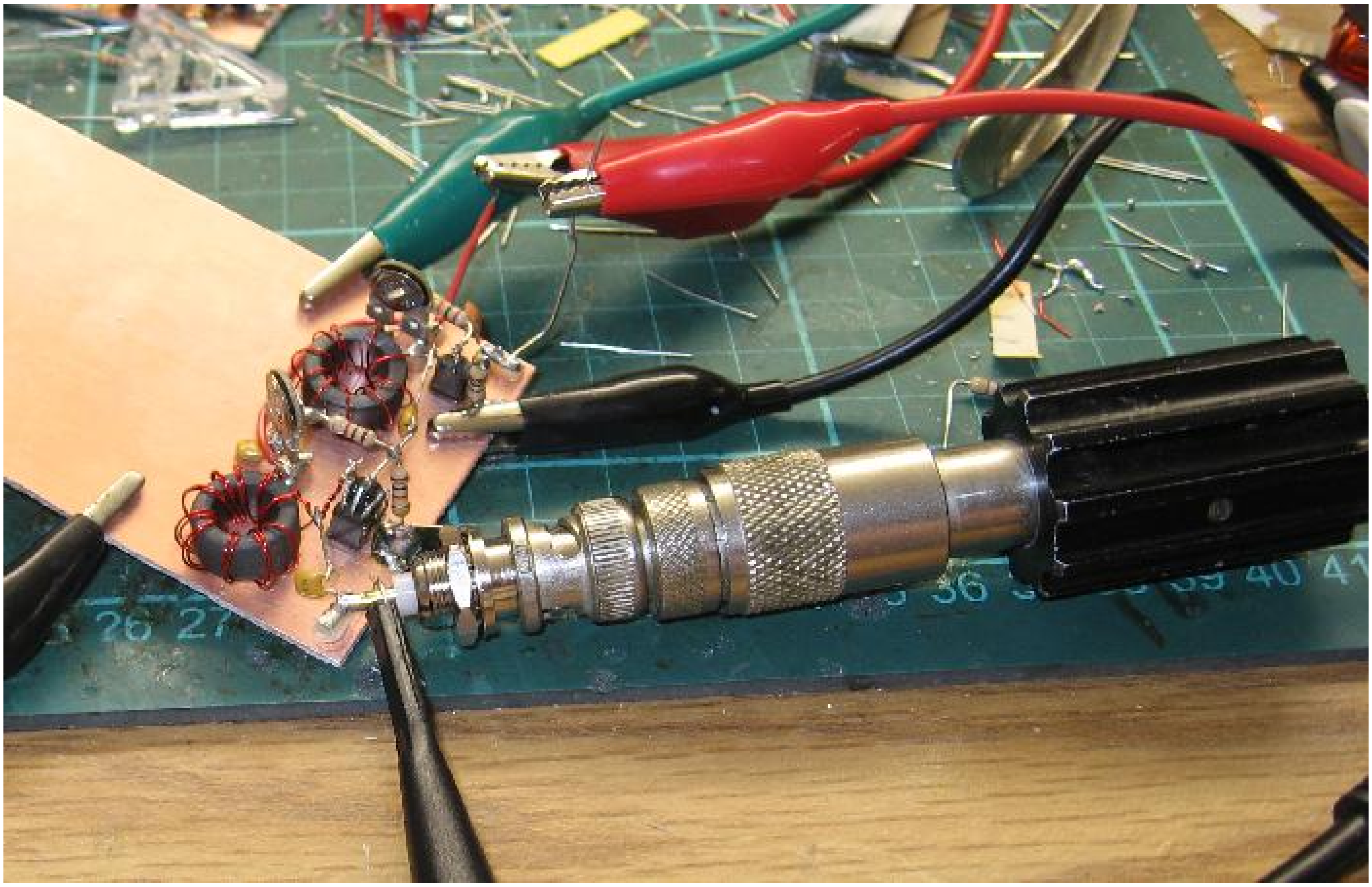
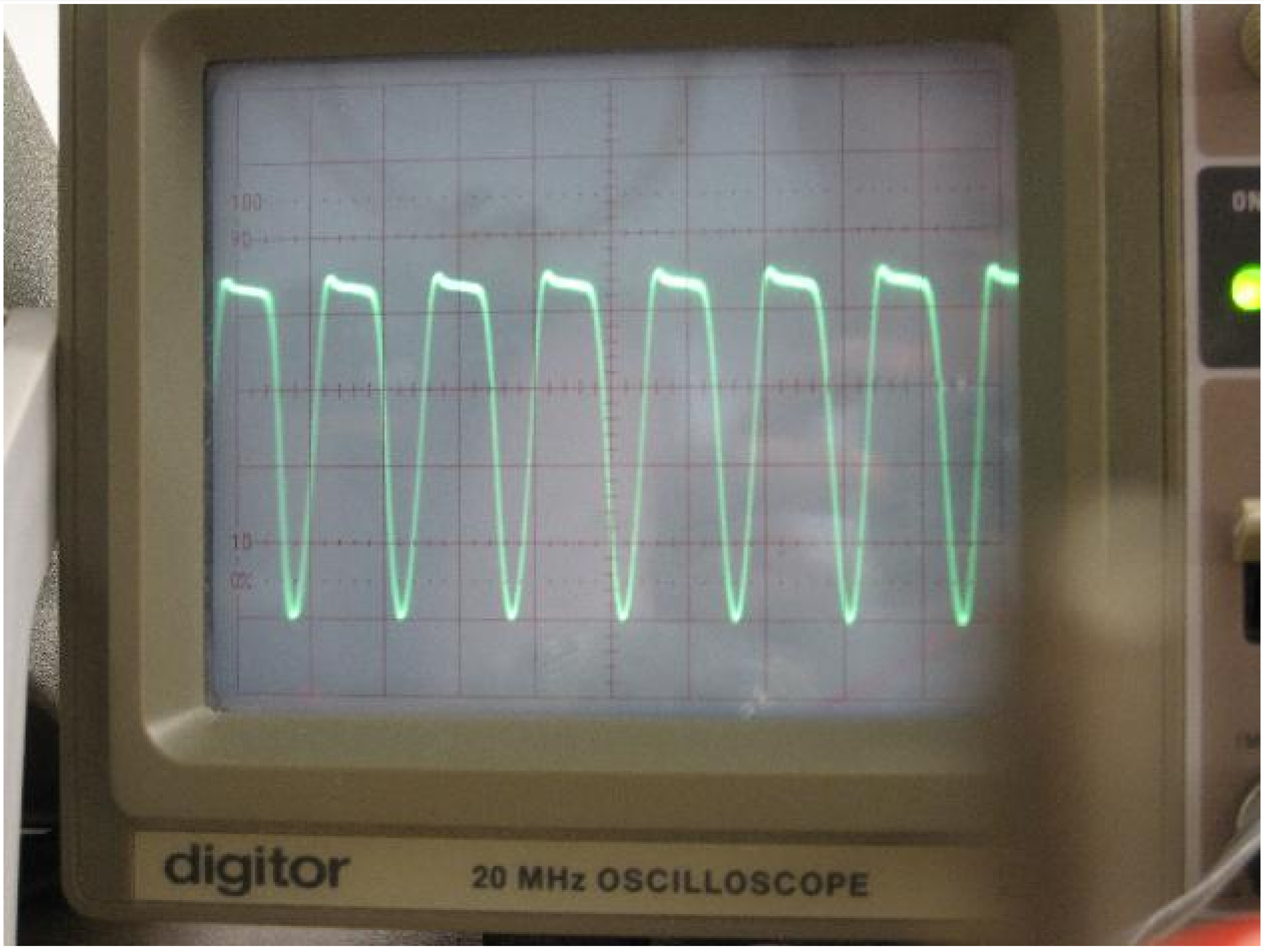
about 680 mW out at a woeful 20% efficiency!

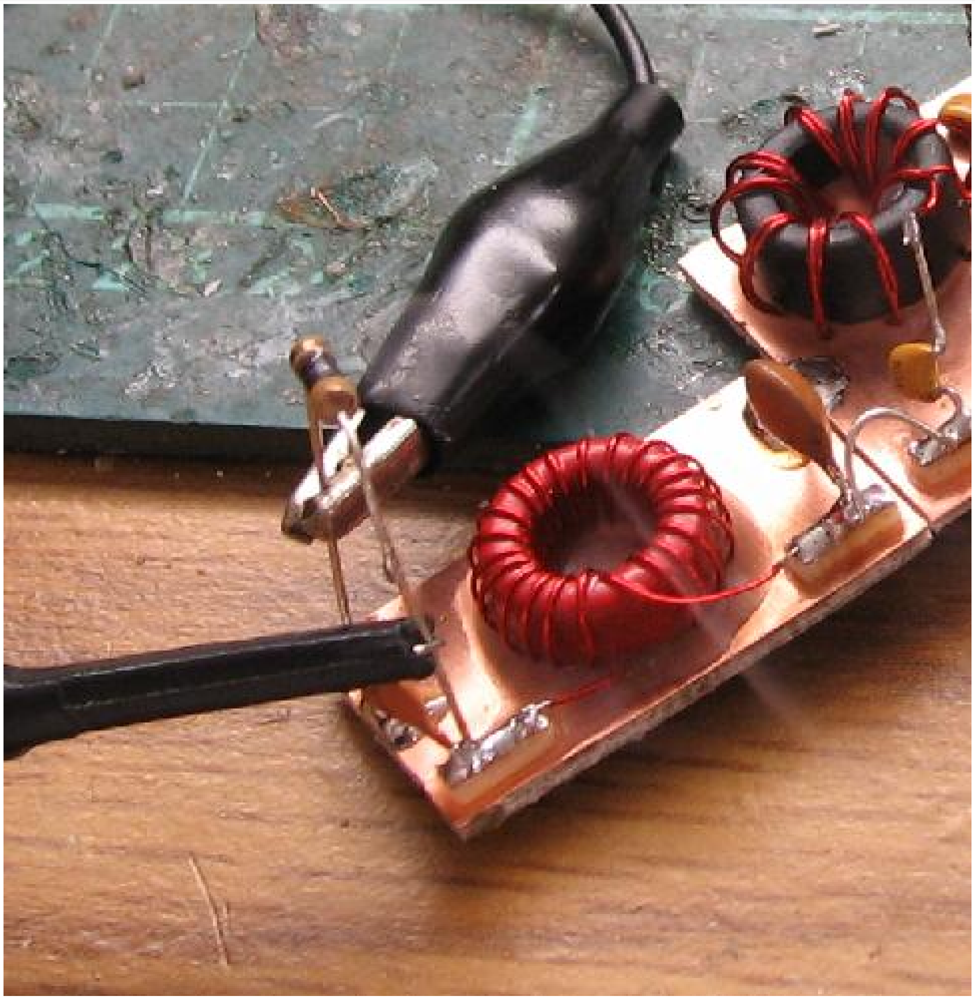


Envelope linearity seems fairly good, but I am yet to do IMD tests on it. The waveform without an LPF looks absolutely terrible! The LPF is *not* optional, without it you will be heard quite well on 40 metres.

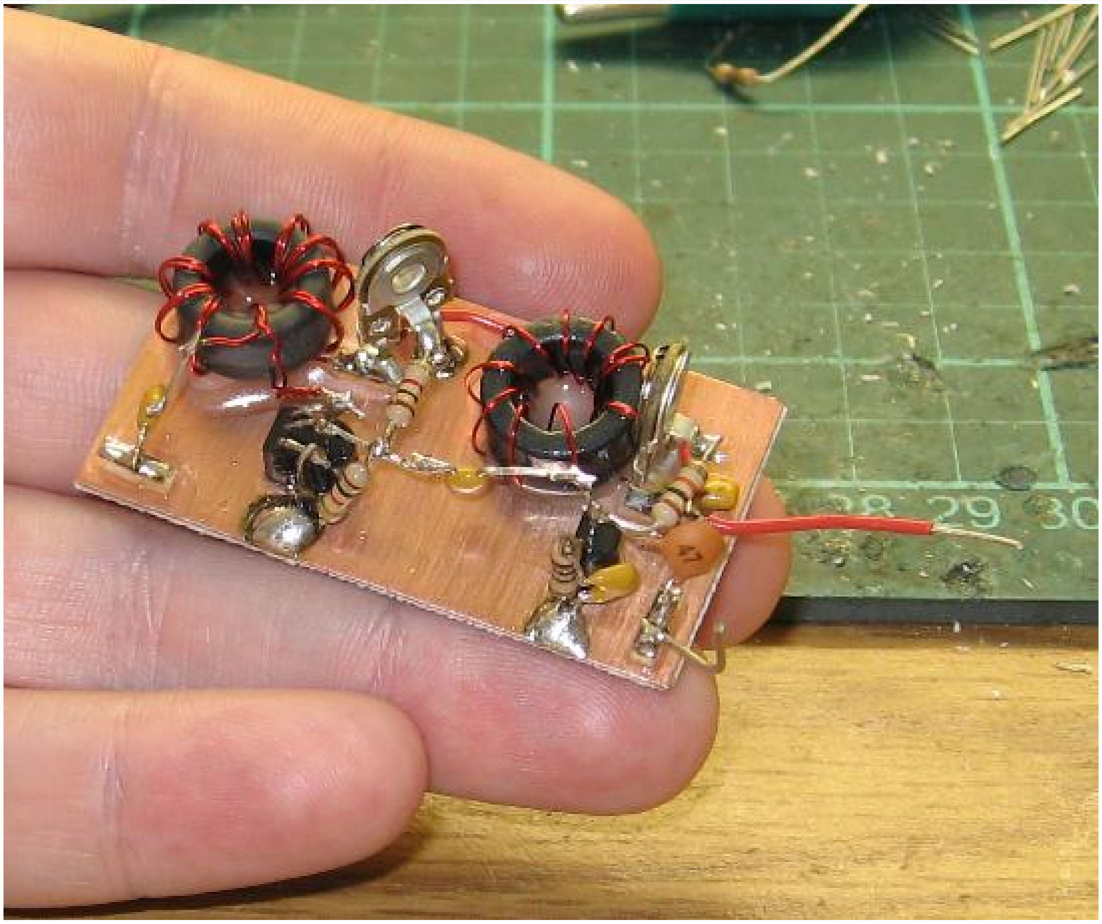


Without a load the circuit is fairly well behaved. It will not pull much current from the supply and appears to be able to tolerate the abuse continuously. Stability seems good with the input floating as well, however is it possible to cause self-oscillation by touching the input and output at the same time - not very advisable! Removing your fingers will stop it. When the input is terminated in a low impedance this goes away.

I didn't try shorting the output, but I did try running a torch globe from it. It wasn't a good match to 50 Ohms, so it largely refused to load up the circuit properly. The amplifier pulled normal amounts of current, but produced little output (a dim glow - and poor voltage across the load). The output devices got a bit warmer than usual, but survived the test (about 2 minutes). This is probably how it will behave into low-Z loads. I didn't fiddle much with reactive loads, and lacking a ready-to-go tuner for 80 metres I suspended testing at this point (I might have a fiddle with an L-network later). I did cook some 1/4 Watt 47 Ohm resistors though - the 20 Watt dummy load got warm to the touch, so there is real power there.



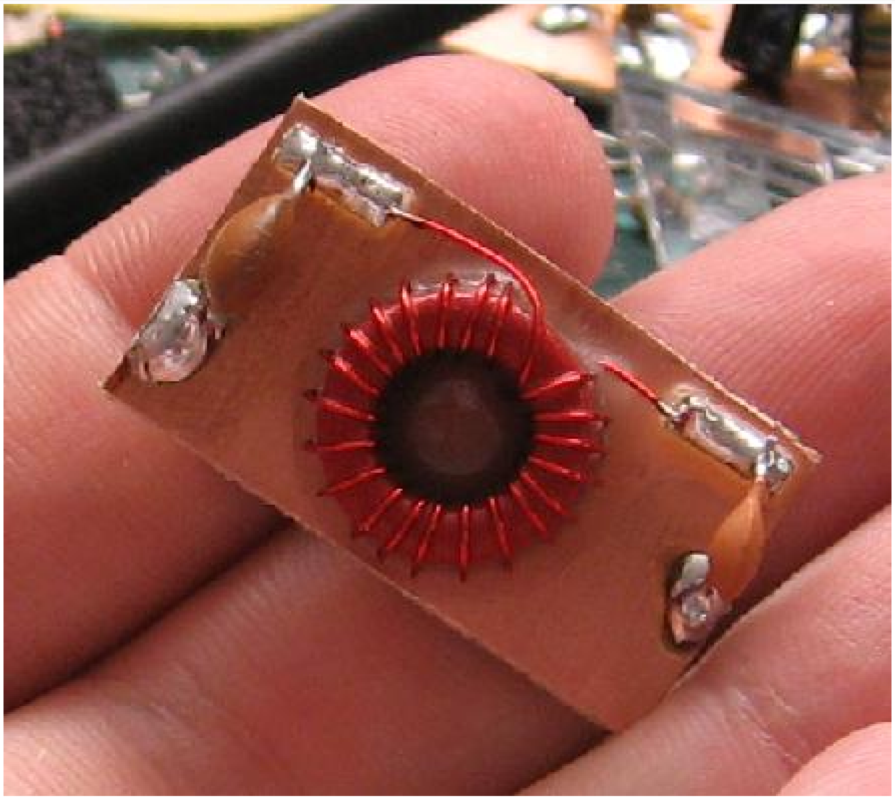
The output devices get quite warm, no doubt because of the poor drain efficiency. Being superglued top-down to the PCB does cool them somewhat. It doesn't get that hot that it will melt the wax I used to hold the toroids in place. The bias current drifts up after cooking the amplifier with 1.6 W out for a few minutes. As the devices cool it comes back down again, this seems to be non-damaging, the 2N7000 is a pretty robust device. Note that this is CW power, not what the amplifier would actually have to contend with in a phone rig like the Wee Willy.



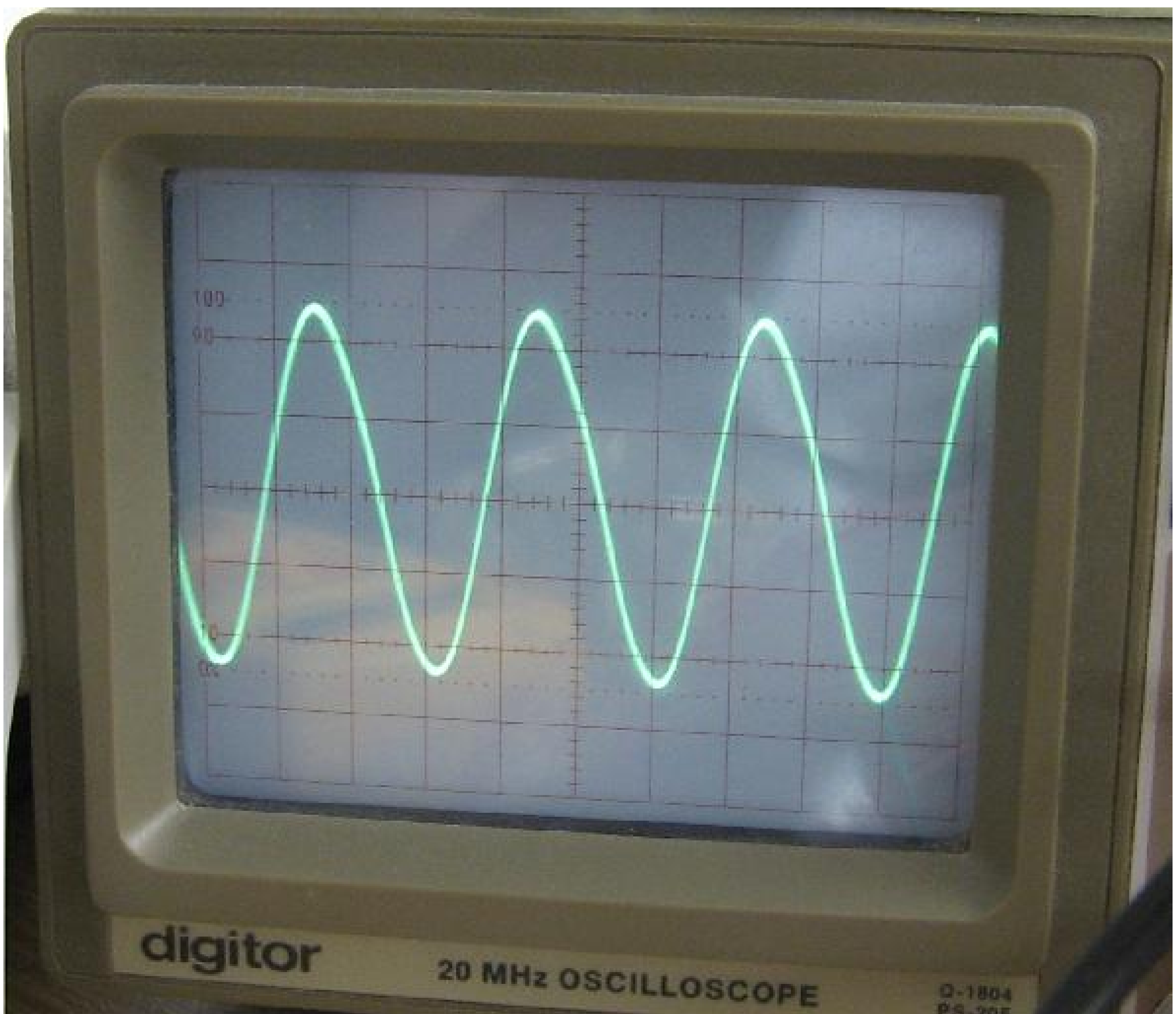
I intend to rebuild the amp at some point with the specified VN10KM devices. Jaycar carries them, but at about $4.00 each, I am hesitant to invest the money when I know the 2N7000 (much cheaper) works just fine. It would be interesting, however, to compare the performance with the devices specified.

Update

I built a LPF for the unit and started playing with it in a practical DSB transmitter using a few other bits and pieces I had laying around.



The signal looks *much* better with this filter in place.



The insertion loss is less than 0.5 dB in-band. The efficiency and power output were not significantly affected by its addition. The stability seems unchanged as well. I tried shorting the output too, it reflects the transformer primary reactance to the collector in a similar manner to open-circuiting the output, so the circuit is poorly loaded and pulls much less current. I still haven't experimented with pathologically reactive loads.

Update 2007-04-09

I've since built the entire Wee Willy (which will be the subject of another article). This time I used VN10KM FETs for the final stage. I can now confirm that the 2N7000 performs identically in all ways, the only difference being the easier heat sinking of the VN10KM devices with the drain-connected tabs which you can solder a heat sink to.

I've also had the 2N7000 and the VN10KM operating at 6 metres delivering over half a watt per device. The VN10KM has internal protection zener diodes, which makes it more robust in theory, but I am still yet to kill either device by load mismatches or severe overdrive. The 2N7000 has less capacitance, which may mean it will operate better into the VHF region, but this is yet to be confirmed.

4 comments.

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The Fredbox

2007-05-26

I first heard about The G3XBM Fredbox transceiver via Solder Smoke. As soon as I saw it I just had to give it a go. It is a very simple and elegant design. Of course it offers no bells or whistles, just a fixed TX and RX frequency, and a flea-power output on TX, but it has a special charm in its simplicity and the retro usage of AM on VHF.

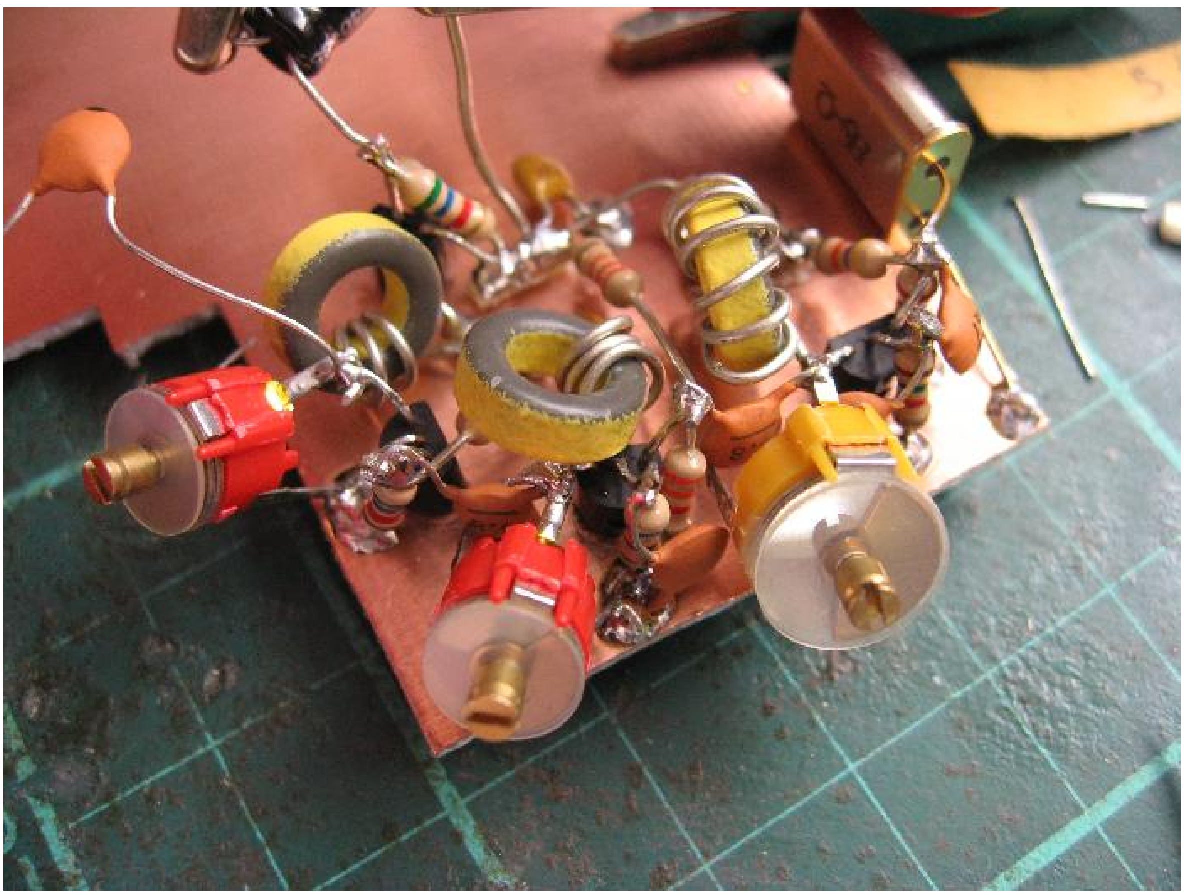
Transmitter

I built the transmitter side first. BF199s were selected as a good candidate for the RF devices, but I lacked a crystal in the range specified in the original article. Instead, I used a common 16.384 MHz crystal and redesigned the circuit to be two triplers rather than two doublers. This crystal is a common "computer" crystal, but places the TX frequency in the high-end simplex segment. This is a bit too close to the pager-splattered end of the band for my liking, and doesn't match the band-plans. For now this is OK, I'll get a custom crystal cut eventually.

I didn't use shielded cans or variable inductors for the transmit coils (as specified by the article), rather I used fixed inductances wound on T37-6 toroid cores with bare 0.71 mm tinned copper wire. My LC resonance calculator and nH inductance meter were enormously helpful in making the selection and testing of the tripler and output stage resonators. Each stage was tuned with trimmer capacitors.

It was amazingly easy to get the TX-side working, I just built each stage from the crystal to the final amp in turn, testing as I went. Each stage is well behaved and peaks nicely.

Peter VK2TPM could hear the signal at his QTH several kilometres away when I connected the half-finished TX board into my flower-pot antenna. The DC input power was about 23 mW, and no special attempt was made to match the output into the load, in fact the series trimmer in the matching network was absent at this point, just a fixed 12 pF capacitor was used for DC blocking.



Upon finishing the TX circuit I did experience a bit of RF pick-up in the microphone amplifier 2nd stage. A 1 nF capacitor to ground discouraged its RF gain and eliminated the problem. The 2nd AF amp stage is located immediately adjacent the crystal oscillator stage and was picking up RF directly. The effect was not audible, but was visible on the spectrum analyser as weak 16.384 MHz sidebands either side of the carrier. This wasn't causing feedback, just high-frequency modulation of the signal. If nothing else it proved the bandwidth of the modulator, which is perhaps a surprise considering the 100 nF decoupling on the modulated rail, however the output impedance of the series modulator emitter is so low it could deliver a few tens of mVs of HF ripple into that kind of load.

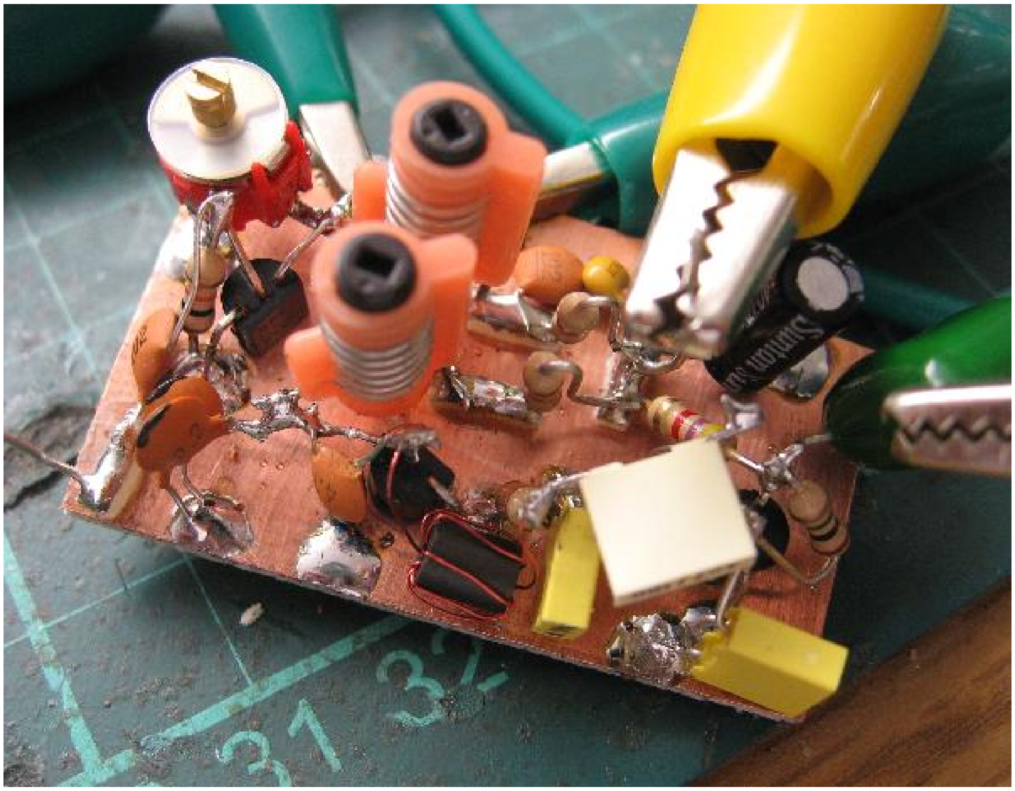
Receiver

As easy as the Transmitter was, the Receiver was hard. It fought me every inch of the way. I spent an entire day trying to work out why it was simply not super regenerating from about 130-160 MHz. It turned out to be a 10 nF decoupling capacitor on the cold-end of the detector resonator. The article specified 1 nF, and I originally intended to use this value, but I had a strip of 10 nF mono's on the bench, so I used them. At build time I did consider why 1 nF was specified in the first place, I figured it was avoid the exact problem that would befall my unit, decoupling resonance. (Lesson #1: Trust the original builder and your initial instinct.) When the unit wouldn't oscillate properly I assumed that I had damaged the capacitor on install - this is a pretty common fault, so I tested it in-place by ensuring it would shunt a HF signal (my standard decoupling cap test), it passed this test just fine. (Lesson #2: Test at the frequency of operation.)

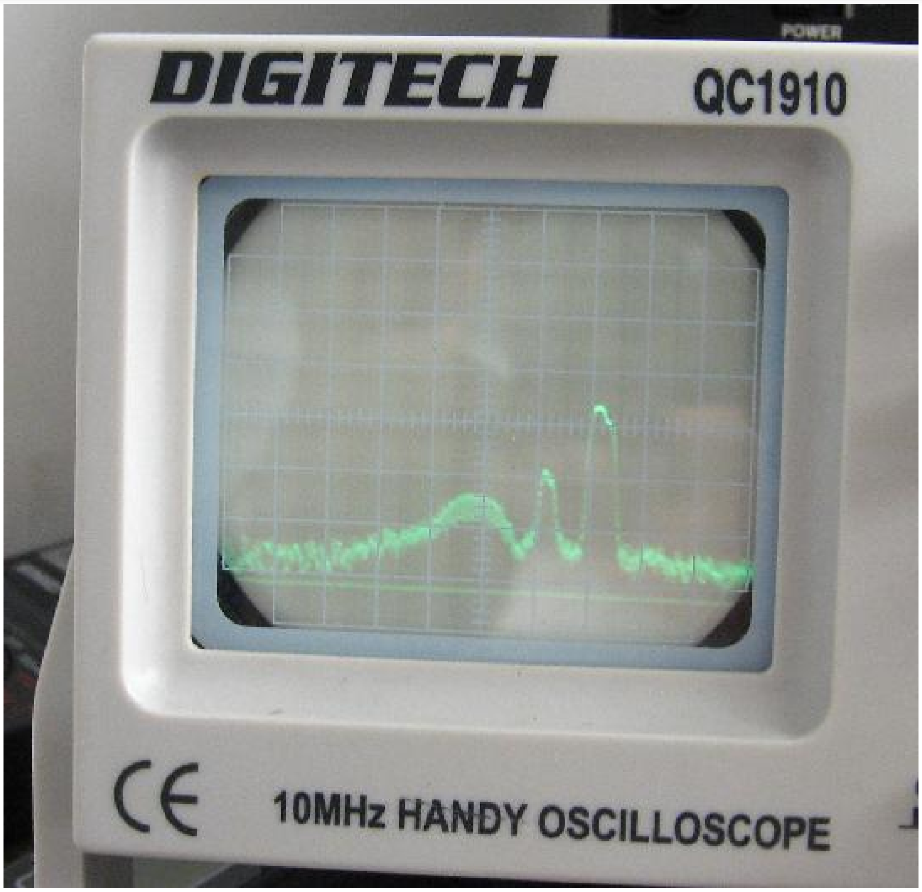
My hubris about "modern components" being superior and likely "purely capacitive" at VHF turned out to be completely wrong. It took *hours* to work it out, but eventually I determined the entire decoupling network was resonant near the operating frequency. Much foul language later and I replaced the cap with a ceramic 1 nF, with its "flashing" broken off and scraped right back to the disc to minimise the lead length. This cured the problem.

For the longest time I had assumed it was the source coil - and in fact the first source RFC I used (a molded choke) was being operated above its self-resonant frequency and prevented any oscillation at all. I replaced it with a few turns on a ferrite bead which seems just fine now.

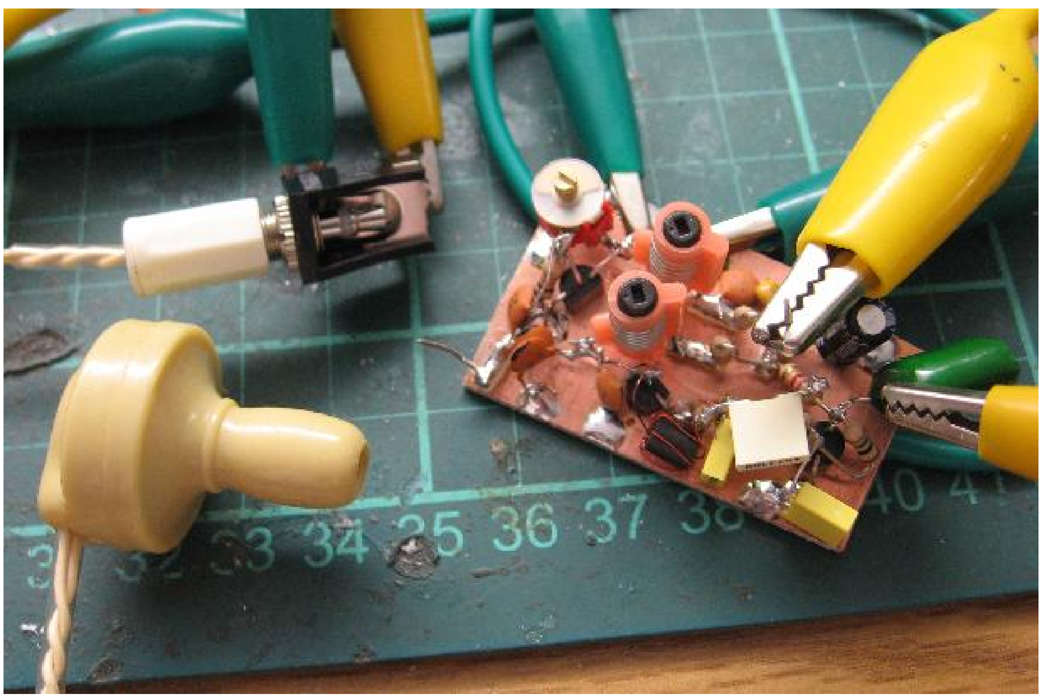
A couple of other minor annoyances/mistakes were worked through (like picking larger inductances and making the entire circuit so sensitive to stray capacitance it was a nightmare to tune - DUH!).



Eventually the unit super-regenerated right through the region of interest and the LNA stage was constructed. Initially I put the LNA drain coil too close to the detector coil and they over-coupled. This meant as I tuned through resonance on the LNA drain it would pull the detector so much it would shut down. Bugger! Moving the coils apart a little reduced this effect to acceptable levels, but the core of one still effects the other a little. I'm happy with the current coupling, and it is actually useful to help tuning the LNA resonator. As you rock it through resonance it will pull the detector, and by observing the wiggle on the spectrum analyser you can tell you've got it tuned up. The AGC action of the detector makes it hard to tune for maximum smoke otherwise, as the AF output doesn't change much at all even when the front-end isn't tuned up properly. Once you've got it nearly right you can use a weak signal to tune for best signal to noise.



Note the pagers above the 2 metre band in this spectrogram. The hump in the noise floor is the receiver super-regeneration side bands. The smaller peak in between is the output of the Fredbox transmitter, the leakage from the unshielded prototype on my desk operating into a 47 Ohm load. It is rather disturbing that the pager signals are *larger* than this local signal just a foot or two from the spectrum analyser antenna.



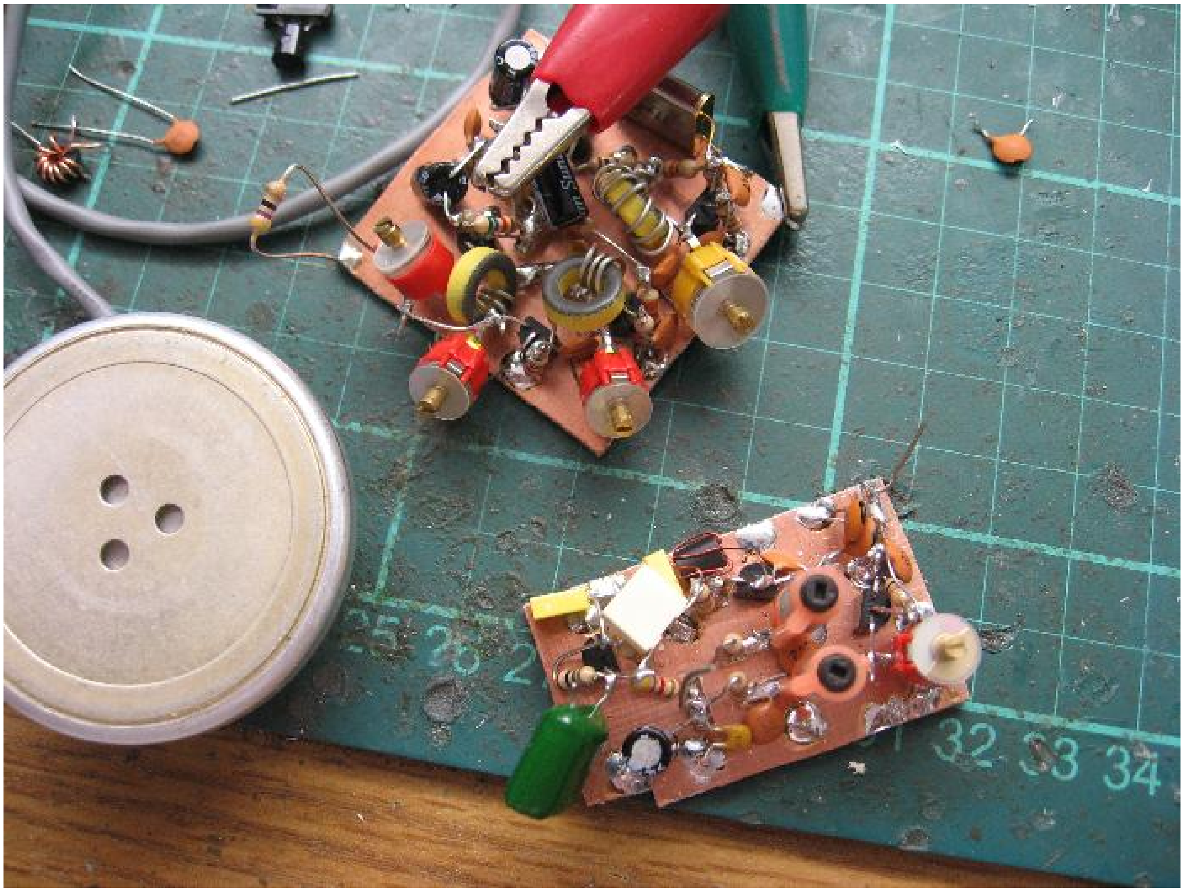
I used J310s for the receiver FETs, and a 2N3904 for the audio amp. Although the main design requirement for Roger appears to have been flea-power, I think a better AF amplifier that can drive modern low-impedance headphones would be preferable. Only Jaycar now carries crystal earphones with a nice soft silicone ear piece. The one I used comes from DSE and it is hard-plastic - not very nice on the ear. I really hate these kind of earphones anyway, I'll probably be rebuilding it for a low-Z output at some point, but it does work pretty well as-is.

BTW: While I was in the "Special Hell" of decoupling resonance I took the RX down to the FM broadcast band, and up to the VHF-hi TV band. It works wonderfully in both, which isn't a surprise. However, by adjusting the drain-source feedback (then a trimmer, now fixed) I

Hall's regen on the FM band. The topology is more forgiving however, allowing grounding of the tuning cap. I also built several different oscillator topologies in desperation before I identified the decoupling fault, in one I got a Colpitts-like oscillator working with emitter coupled feedback to a tapped capacitor across the tank. This is something I should have thought about a *long* time ago, I'll probably build yet another FM broadcast regen using this topology for the detector, it seemed quite easy to control just by manipulation of the base voltage.

Boxing It Up

I am still tossing up between a cast Aluminium box, a custom box folded out of Aluminium sheet, or an Altoids tin. The circuit is small enough to just fit inside an Altoids tin but it probably won't fit with a battery. I'll pick up a centre-off momentary-one-side switch over the next week and finish off the radio one way or the other.



Note the use of an old telephone receiver as the microphone. It is nearly as large as the entire TX board. I'll have to find my electret mics, I know I have a bag of them somewhere that I got from a Rockby sale.

I'm strongly considering rebuilding the radio, perhaps through-the-hole to minimise its size. Although my prototype isn't too large as-is, it would be nice to neaten it up. Maybe I'll build it with fixed caps and variable inductors to save space too, although shielded cans are about the same size. It *might* be possible to tune the multiplier stages with stretched coils and fixed caps, this would make it much more compact and save money too if it ends up being kitted...

More TX Power

I am considering running the unit on 12 Volts to get a bit more RF out, and perhaps building in a small amplifier to get it up to 1 Watt region. This would probably involve a rebuild of the TX side to use a 2N4427 or similar final device, and a more robust series modulator transistor. This won't be efficient, but is probably easier to get going than a linear amp which would need careful drive adjustment.

I'll probably conduct some experiments around using a 2N7000 or VN10KM as the output device. The math suggests they may operate on 2 metres. I've already got them working on 6 metres in a brief experiment last month (must document that).

Comments

Working with VHF is fun! I find it a great learning experience, especially when you get problems like the resonant decoupling cap. That kind of thing really pushes your understanding of the physics and teaches you a lot.

I know a lot of HAMs won't touch anything above the bandwidth of their oscilloscopes. I can understand the frustration when something doesn't work, especially when you can't see why, but it really isn't that much worse at VHF. With just a diode probe you can achieve a lot. It does help enormously if you have VHF test equipment, for example I likely would have never noticed the HF modulation problem had I not had a spectrum analyser (although the HF was visible on the collector of the modulator drive amp, and most of us have a CRO that can see fine near 16 MHz).

A wavemeter can be helpful, if a bit retro, especially for making sure your multipliers are tuned up right and for looking for spurs. You can build one quite easily, it only needs to be a resonator with a detector and a LED or meter as a read-out. I'm a big fan of the biased 1N5711 through the decoupled bottom of the tank coil topology. For super-sensitivity you can use a MPSA18 as a DC amplifier. With a signal generator or dipper and a counter or scanner/receiver you can easily calibrate it. It can be used like a poor-man's spectrum

My only advice when you get stuck is to trust the physics, do the math and follow your instinct when nothing is making sense. Rebuild parts of the circuit and test them independently. Measure what is actually happening and try to figure out what kind of misbehaviour in the circuit would cause the observed of behaviour. That will often solve an otherwise intractable problem.

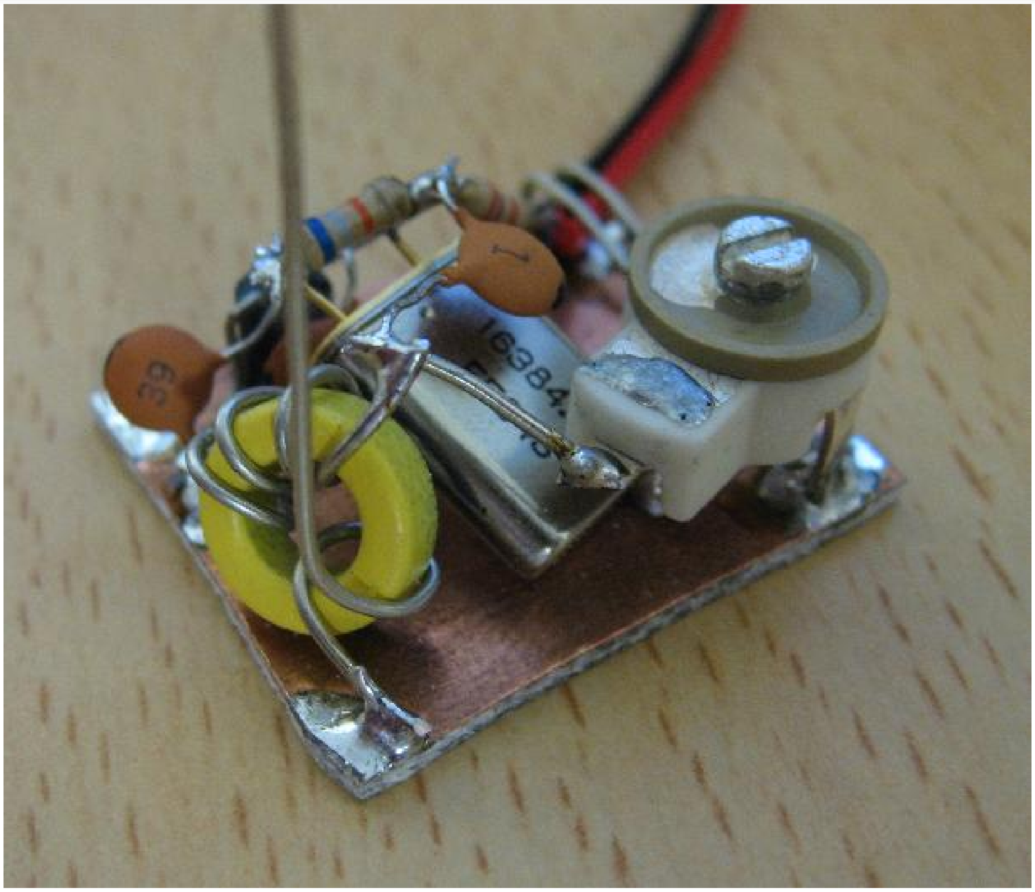
Update 2007-06-05

I took the Fredbox boards to the local Homebrew Group meeting. I had both halves hooked up and talking across the room. Peter VK2TPM had brought along a digital audio recorder and did an interview with many of us in attendance. You can hear what I said about The Fredbox on Soldersmoke 62, and even a brief snippet of audio going through The Fredbox.

Also on the recording are Peter VK2EMU talking about the 80 meter challenge, John VK2ASU talking about his transmitter modules for the challenge (and an interesting diversion into IRF510 gate-modulation with some input from Brian VK2TOX - something I was thinking about back here, apparently Drew Diamond VK3XU has already produced a design doing just this). Mike VK2BMR also talks about his great VSWR/power meter project. His unit was absolutely beautiful, I was very much taken by the excellent job he did of cutting the PCB stock that made up the external directional coupler box, essentially flawless, perfectly square workmanship.

Update 2007-06-09

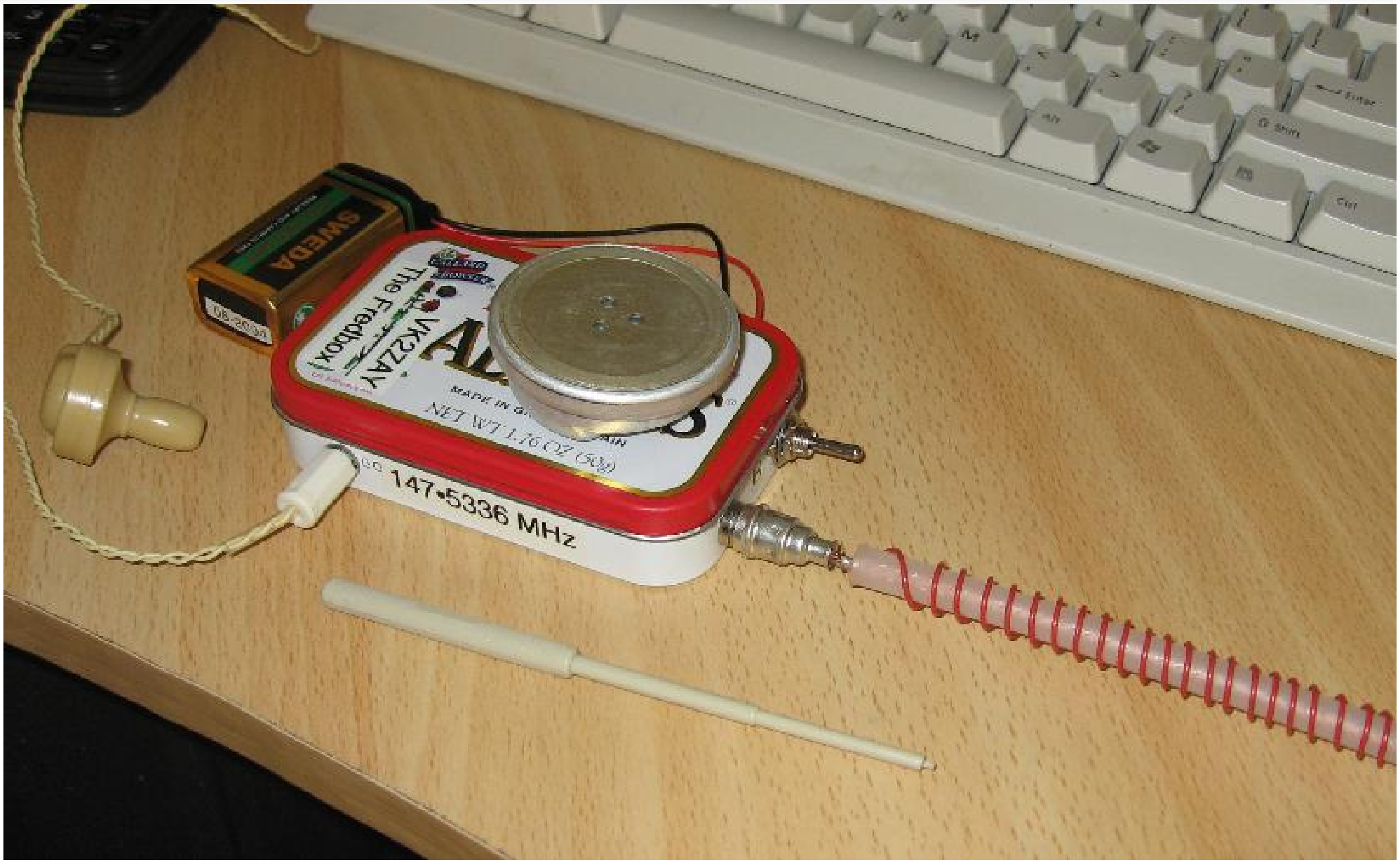
I've built a weak-signal source for aligning the receiver. One of the biggest weaknesses of the Fredbox receiver is that it drifts in frequency quite significantly with Vcc variations. Powered by a 9 Volt battery near the end of its life, it may drift enough to make the receiver completely off-frequency despite its poor selectivity. If I build this circuit again I'll probably put in a stabilized supply for the detector stage to avoid this problem.



The signal source is a Pierce oscillator driving a tuned circuit which selects the VHF harmonic of interest. Because of the oscillator topology the crystal isn't pulled down as much as in the Fredbox circuit. The difference is fairly minor for my purposes, the poor selectivity of the receiver makes the difference in frequency of no real consequence. There is no active (or passive) multiplier, so the tuned circuit is merely extracting the harmonic energy from the oscillator. The harmonic energy available is very small, which is perfect for the application, giving an almost undetectable signal 1 metre away.

Update 2007-06-10

I've boxed up the Fredbox. As discussed earlier I went with the Altoids tin, despite this not allowing the battery to also fit inside the enclosure. I tossed up soldering an additional tin to the back to hold the batteries, but for now I've gone with the 9-volt battery snap just hanging out. It will work well with 6xAA battery holders which can just be held to the box with a rubber band.



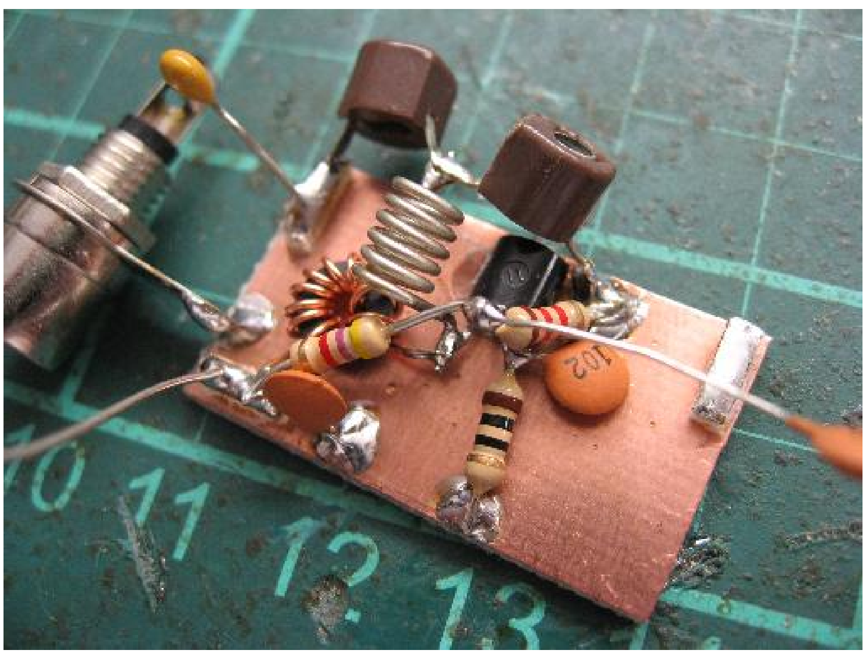
For the RF connector I chose an RCA. I can hear all the VHF engineers cringing, but for the purposes of this prototype it works just fine. The Antenna is a half-wave of wire helical which is quarter-wave resonant (with some pruning). The former is a piece of centre conductor and insulator from RG-213 coax. The centre conductor was left in place and is soldered into the RCA plug centre conductor, adding some capacitive loading and shortening the length of wire needed for resonance. I have no idea if this is good or bad, but it works.

I didn't find my stash of electret microphones, so I ended up just soldering the telephone receiver into the top of the Altoids tin. Ugly as hell, but also kinda unique. It looks somewhat like those Vietnam-war era VHF-low walkie-talkies.

I couldn't find a momentary-one-side toggle switch, so a centre-off on-both-sides switch was used instead. A special dummy load/diode peak-voltage probe was assembled for the final alignment. The carrier power ended up being near 25 mW on 12 Volts, on 9 Volts 10 mW just like Roger says in the article.

Update 2007-06-11

The 2N7000 on 2 metres experiment was a failure, it simply doesn't produce useful power beyond 90 MHz or so. However, it is very usable below 70 MHz. My input network was far from optimal, so perhaps with some more work it would be possible to get it working higher up, and I haven't tried an VN10KM in the same circuit.



I've also been fiddling around with grounded-base class-C multipliers. (Not just decoupled, biased base, the base actually soldered directly to the ground plane.) At first this seems a little weird, but if you pull the emitter low with a link-coupling to the previous stage collector current will flow. The advantage is excellent reverse isolation, which might help with stability with less than ideal layouts and devices. Such a topology was apparently quite common years ago with the 2N918.

1 comment.

Alan's Lab

me and my geeky hobbies

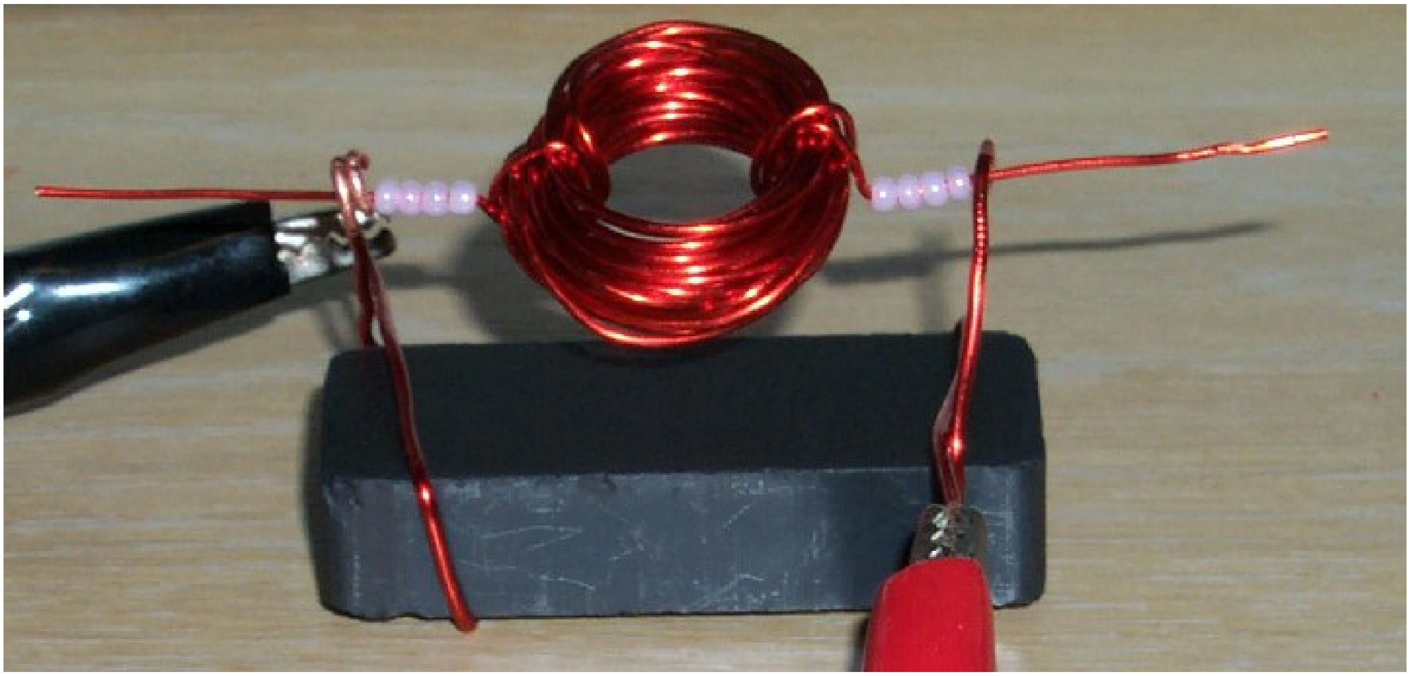
search

Home Twitter YouTube Calculators

Trivial Electric Motor

2002-10-17

OK, so its a child's toy, but lately I've been getting into simple things that show physics principles. Most importantly, trivial projects like this keep my hands dirty, in the world where I spend more and more time behind a keyboard.



At first sight it is very simple, a coil, a magnet and some beads and bearings. But then you start to think about how it works. It appears to have no commutator, how can it work? Well actually it has a commutator, only half the enamel is stripped from the wires (one side, facing away from the camera), so the coil is active only half the time, inertia takes the coil around until it contacts again and gets another torque kick.

This is an excellent project to build with your children. It is simple, takes only minutes, and is instant gratification. Once assembled it runs up to speed quickly and rattles and shakes all over the desk. The physics are easy to explain (perhaps not to understand mathematically, but it all helps) and it works, they built it themselves, unlike some cold diagram in a textbook.

You might like to make your bearings out of bare wire, saves the stripping which took me the most assembly time. The power source is a D cell, which will run the motor for over 24 hours (I've timed it). The armature is wound on a AA cell or similar diameter tube. Being square would actually be better, and different sizes and turn counts all work with different outcomes, lots of experimentation there! My original prototype was 6 turns, this one is 40 turns, they both spin about the same speed, but the 40 turn one requires less magnets and produces more torque. The magnet is the strong boron magnets you used to get from Tandy (aka Radio Shack). They were once about 50c each, now they want something like $4.50 for them, but you can still get them if you are looking to build an exact replica.

The beads are just to keep the armature centred in the bearings. You don't really need them, but they help with the speed and consistency of the motor. My original prototype was held between the open alligator clips and worked fine. Don't expect it to self-start, it may if there is electrical contact, but you'll probably need to give it a small flick to get it going. A good replacement for my magnet would be the head positioning servo magnet out of a junked hard disk drive, just note the pole placement is a bit strange, but they are very powerful (perhaps too powerful, they give blood-blisters if they pinch you against the fridge for example).

Here is the parts list if you are shopping for it in Australia. Chances are you will be able to source all the parts for free, but worst case you can buy all the ideal parts you'll need at the local mall for about $10:

Part	Where	Price	Notes

 XHTML | CSS | CSS toggle

mm magnet wire.	Smith, Jaycar, or Tandy.	a 25 gram reel.	money, the 25 grams is way more than you need, it would make 20 motors. The gauge is not that important, #22 or #24 is the easiest to use too thin and it can't support the weight, too thick and it becomes impossible to bend.
Fairly strong magnet.	Jaycar or Tandy.	$4 for a good one.	Magnets from science stores or electronic stores are priced very high, don't buy them there. Scavange for them, old speakers work great, as do old hard disk drives, stepper motors, or anything else that has perm magnets in it. The poles may be in strange places, but they will probably still work if you experiment with the placement. Fridge magnets won't work unless they are the solid disk or bar type, the flat polymer ones are too weak and have alternating poles closely spaced.
Small plastic beads.	Lincraft.	$1 for a pack of 50.	My girlfriend dontated a small pack from her cross-stitch supply for this project. They are not strictly needed, but make operation much nicer. You could use a small length of soda straw instead but your bearings would need to be larger.
D-Cell holder.	Dick Smith, Jaycar, Tandy.	$1.25	You may as well get a good D cell holder. You can just tape wires to end of the battery, but the cell holder makes it a no-brainer and saves connection problems. While you are there, buy a small switch and hook it up in series with one power lead, that way you can turn it on and off easily and save juice.
D cell battery.	Anywhere.	Varies, $5 for 4.	Any old D cell will do, you don't need fancy ones.
Gator test clip leads.	Dick Smith, Jaycar, Tandy.	$3 for a pack of 10.	Always handy, not strictly required but saves twisting wires or soldering, and you don't need a switch that way. Reusable and a must for any electronic geek.

In addition you'll need some tools, I used the pair of pliers and knife in a Leatherman to build the whole thing sitting at my computer at home. The hardest part is winding and bearing only one side of the wire for the armature. One leg can be completely bared, I realised this after I carefully bared only half of each side. The main thing is that the bared side be the same on each end. You can make the motor run a little better by adjusting the phase of the torque spike, just twist the wires slightly so they contact later or sooner. Quadrature is probably the best.

2 comments.

Updates

2002-11-10: Bill Meara N2CQR writes
  My first meeting with Bill of SolderSmoke fame.

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Tube Regenerative Receiver

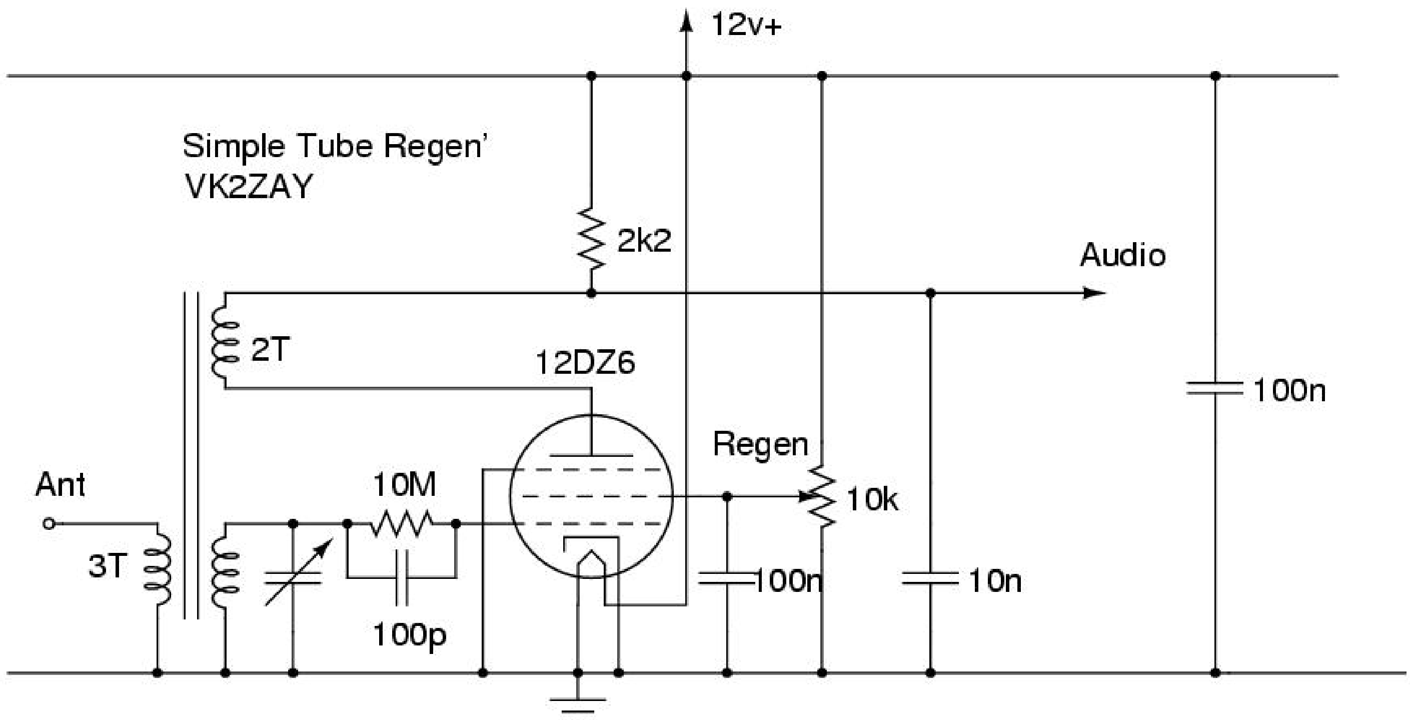
2001-08-27

Inspired by an old movie I saw one late night, I thought I'd have a crack at building something with tubes (this was my first tube project). I was a bit turned off at the thought of having to build a 90-250V DC supply (or lots of 9v batteries) just to experiment, so I took a look at the tube data available online. After a bit of digging, I found a range of fairly modern tubes that are designed to run very starved, just the ticket I thought, so I ordered 4 12DZ6 units and matching bases from The Tube Store

I ordered them on a Sunday night (local time), and they arrived on the same Friday. I was pretty impressed, as I had requested the cheaper shipping that is ment to be rather slow. They arrived nicely packed and in good shape.

That Saturday, I had some spare time to burn, so I set a tube up in its socket with lots of alligator clips, playing around with it, I was surprised how FET like it was, just like a JFET only more forgiving, more legs and gates, and much bigger and hotter.

Using a fairly conventional BRF981 style regen design, I 'ported' it to the tube.



The unlabelled tank is a tuning gang and coil determined experimentally for the bandspread required.

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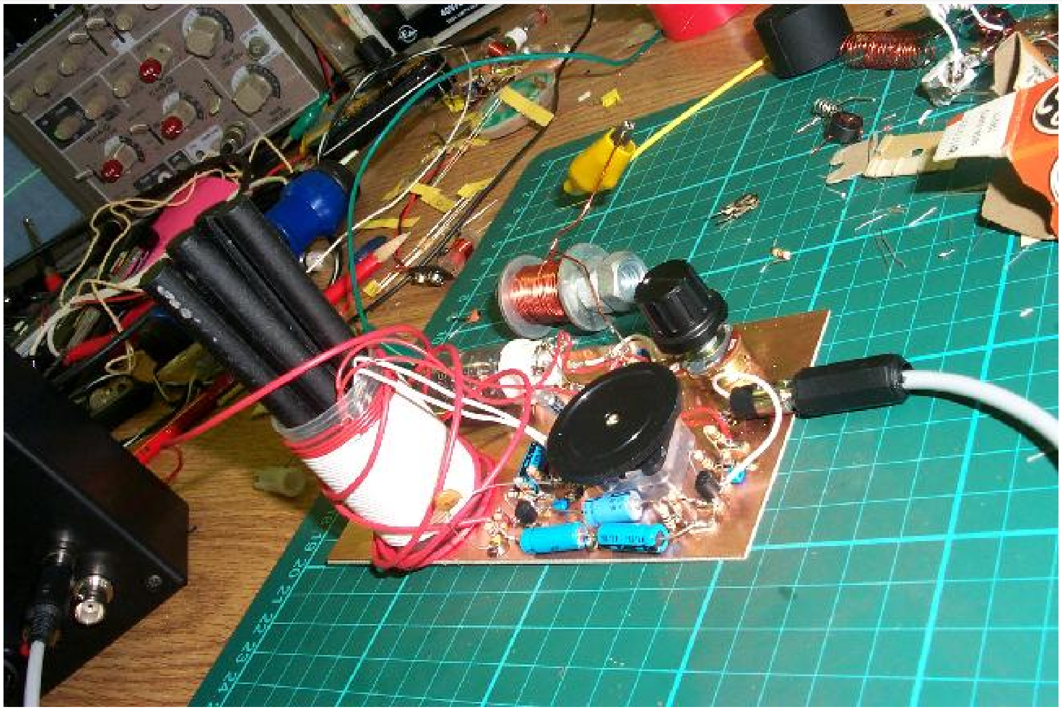


I built the prototype on a chunk of single sided unetched board (my favourite construction technique, a cross between ugly-bug and Manhattan). The coil was just a random bunch of turns on a film canister, it just happened to have holes in it from a previous project that were perfect for the tickler and tank winding lengths.

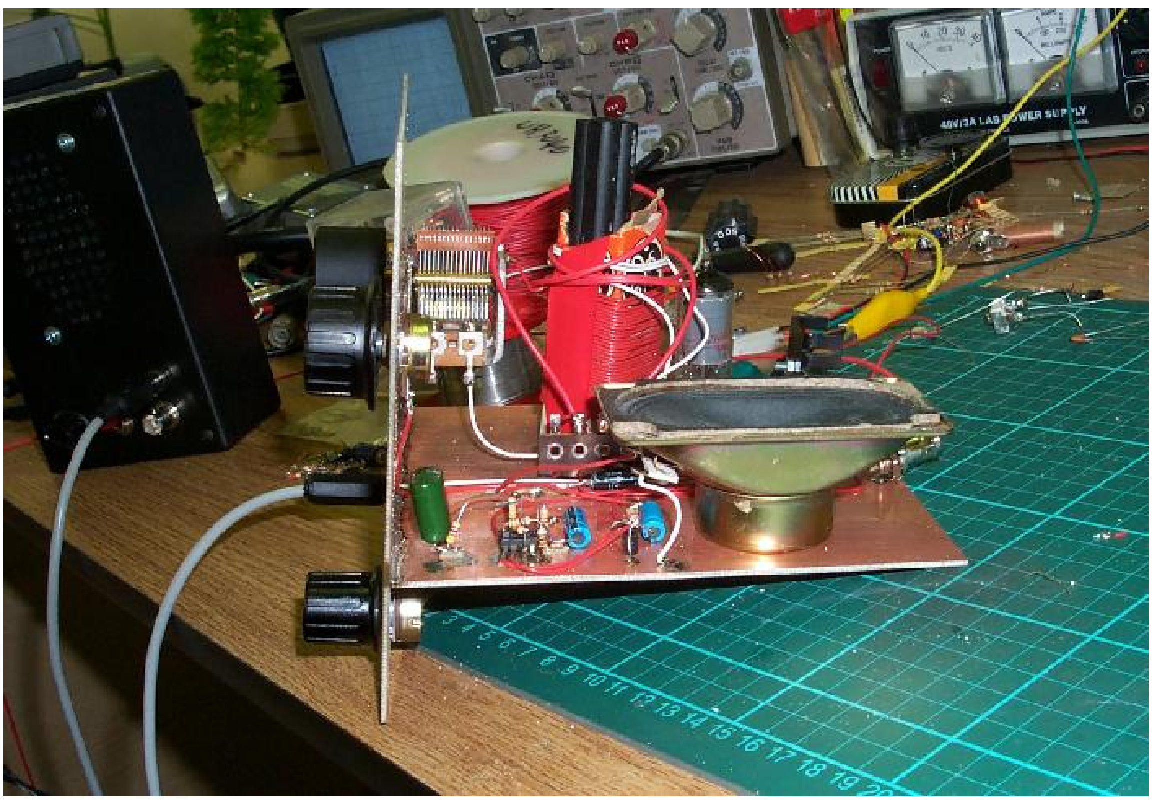
The antenna coupling coil is just some turns wrapped around the resulting structure and soldered to the ground plane. The ferrite rods you can see are some random ones I picked up at DSE for $1 each. I have no idea what material they are, physically they are hard enough to blunt my hacksaw blades, and quite resistant to shattering, even when notched (they are like tungsten carbide or something, but more elastic. The only way I could cut them for a later coil was to clamp them in a vice and beat on them with a hammer until they shattered, hopefully at the right length). Whatever the designation of this ferrite, it is unlike any I have seen before, I must try to measure its properties some day.

Here is a close-up of the prototype in a largely finished state, note the ugly 200p cap just dangling there in mid-air. I took the picture while I was finding out just where on the band it was working. The choke wound on the bolt is to prevent my PSU from oscillating. It has been playing up lately when connected to capacitive loads, I must fix it.

Also note the little black things with three legs littering the board (well there is only two of them). I ran out of room to use another tube for the AF stage, so I resorted to transistors, and built around the tuning cap (it was an after-thought really). The amp stages are identical, fairly conventional AF designs with a gain of around 10dB each, I have not included a circuit for them as they don't appear in the final version and you can replace them with you favourite building-block AF pre-amp. The just visible black thing that the AF lead heads off to is a small desktop amplified speaker. This arrangement provided enough gain to listen to DX stations while I built its daughter (the slightly better designed and more attractive version)

This image comes from about half-way though the construction, the surfaces are unetched single-side PCB material with a solder fillet holding them together. I was concerned about its mechanical strength, but it is more than capable. The front panel has a largish knob for the tuning gang (a ~315p unit I purchased in a lot 20 from Antique Electronic Supply, another rapid shipment and very reasonable prices). There is also a smaller but still quite large knob for the regen control pot, and a medium knob for the AF gain pot. There is also a 3.5mm mono headphone jack, headphones being the main target output device, although the desk amp works well, and the internal speaker is OK for local stations, if a bit tinny because it has no resonant cavity.

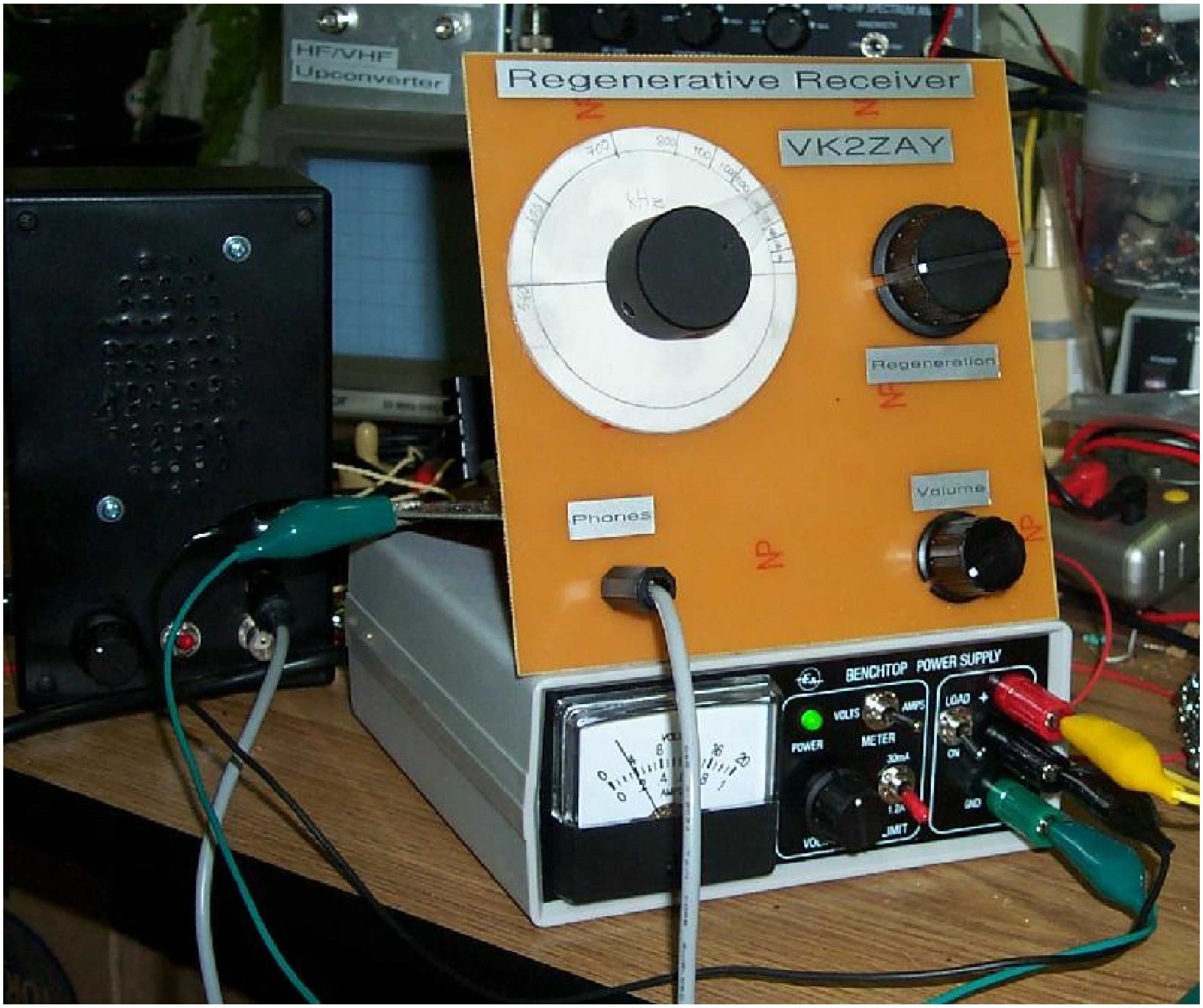
Just behind and to the left of the unit, the prototype is cluttering up my workspace, as I listen to some DX broadcast station (it is about 3 AM by now). It IDs as 'Radio 16 NTC' and I can hear other copies of its content elsewhere on the band, it plays country music. I am told this is a new network of country channels...



Here is the almost complete unit. There is no finishing touches to the face plate yet, and the coil is still a temp' one I wound on the tube box. The AF amp in this unit is almost identical to the one in the desktop amp the unit is plugged into, except it uses a cheaper (and nastier) LM1458 rather than an LF353, and the preamp stage has been given more gain and a different frequency response.

Note that I've added a 3 terminal regulator (the thing with the heatsink behind the speaker) so I can run the thing straight off my 15V PSU without reducing the heater life.

You can probably see the tinning on the board near the big green-cap, I originally built the unit with a three-stage direct coupled AF amp (100dB design gain) but the rest of the circuit is too microphonic for that. The transistors I used in it were labelled BC549C, but they were pathetic, quite noisy and low gain. I used carbon resistors too, which only made things worse. Maybe some day I'll rebuild the amp using metal film resistors and good quality BC550Cs.



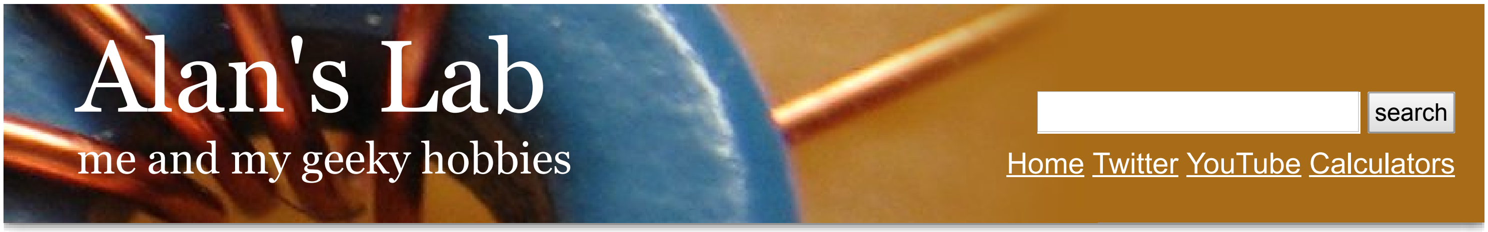
The finished product. The coil is socketed with a 5 pin DIN connector, allowing bandswitching. The tuning knob has a clear plastic needle overlay, and some 'dynamo' style labels have been added to the other front panel features.

I haven't ripped the prototype apart either. It is a workable radio in its own right. I may recoil it for WWVH and build a rather power-hungry stratum-0 clock receiver for the local network.

5 comments.

Attachments

title	type	size
circuit postscript source	application/postscript	12.636 kbytes



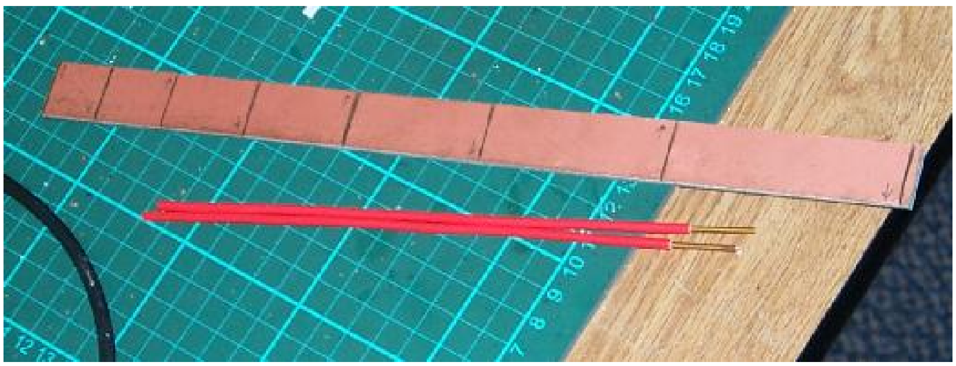
UHF Log-Periodic Array

2001-10-27

Presented here is an experimental LPA for the Australian UHF broadcast TV bands IV and V. They span about 520 MHz to 820 MHz. The original design was started when a friend wanted to build a cheap and effective TV antenna for his girlfriend's TV.

The boom/feeder is constructed out of PCB material, two strips of single sided fibreglass substrate, with about '1 ounce' copper cladding. The material is available from DSE in 300mm square sheets, so one fundamental constraint on the design was a 300mm boom length.

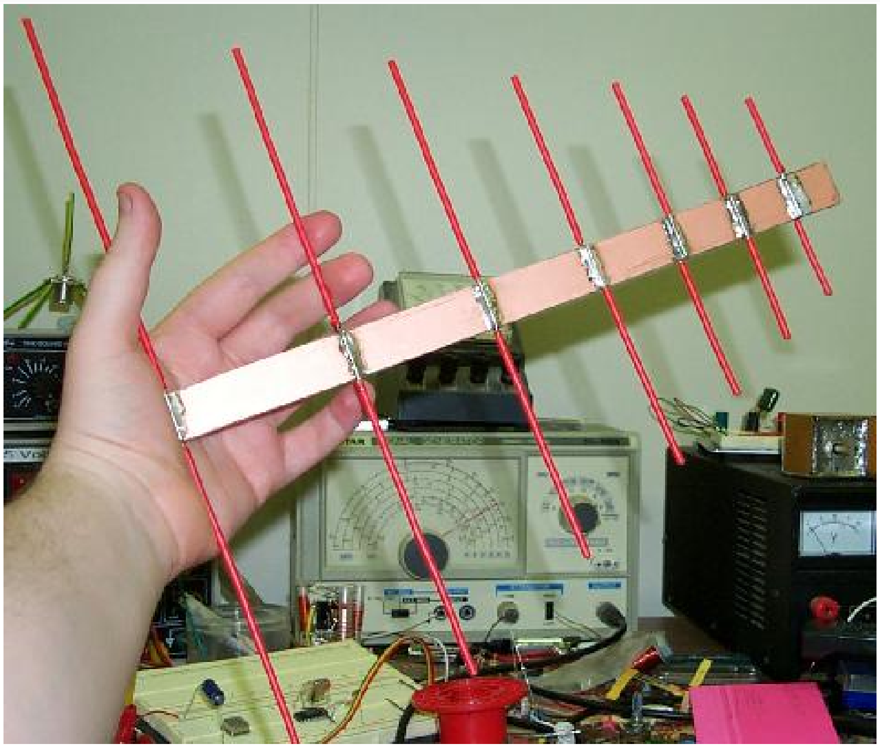
This constraint puts Tau at about 0.8 and sigma at 0.11, giving approximately 6 dBi of gain and a fairly flat VSWR profile across the design range. Originally the PCB/transmission line was carefully designed for 75 Ohms, but the dimensions required were mechanically challenging owing to the high dielectric constant of the substrate. 20mm wide strips, glued back-to-back was the final choice, mainly for its excellent mechanical properties rather than any real Zo design point.



Here you can see the boom marked with element spacings and reminders about the phasing of alternating elements. The two largest elements are also seen, like all the elements, about 20mm extra length was cut, and trimmed as the final construction step. The boom is already laminated at this point, common super-glue was used for this step.

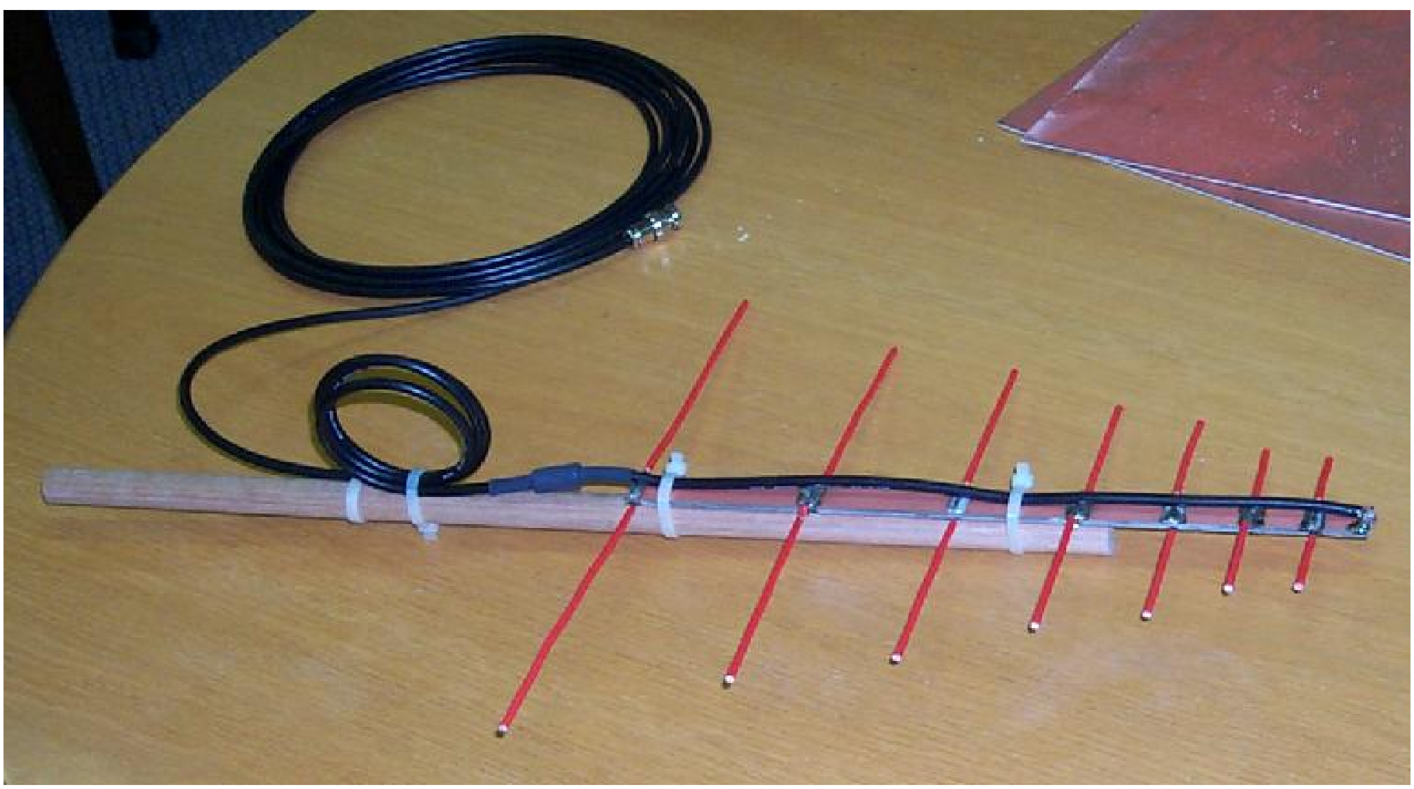
Element	Tip-Tip Length (mm)	Spacing (mm to next element)
1	343	75
2	275	60
3	220	48
4	176	37
5	141	31
6	112	25
7	90	20

Eutectic Tin/Silver solder was used, again not for any particular design purpose, it was what was plentiful and on hand. The higher melting point of this alloy compared to normal Tin/Lead solder made holding the shorter elements while soldering them to the boom quite a painful experience. The elements themselves are 1.5mm diameter solid copper wire, from the centre of heavy-duty mains cable.



The array is fed directly by 50 Ohm coax (DSE branded RG-58CU in this case). The feed point is as the 'sharp' end of the array, the braid simply going to one side and the centre conductor to the other. A sleeve bead choke of VHF/UHF ferrites helps maintain balance, as does an air-wound choke coil in the coax. Some experimentation was performed with the placement of the sleeve choke, the final decision was to take the coax along the braid connected side of the boom/feeder and place the chokes beyond the end of the boom. There is no terminating stub. This arrangement produced the cleanest pattern

A short piece of wood dowel extends the boom and provides a mounting surface. Nylon cable ties are used to hold the feeder/boom to the dowel and dress the coax from the feed-point back along the boom.



Performance testing is work in progress. So far the antenna shows excellent balance for such a simple feed. The first null is outstandingly deep (full) and symmetric off either side of the main 60-90 degree lobe. Polarization purity is also excellent, with full nulls being achieved by cross polarization. Tests have were carried out by ear, eye and S-meter, using the local North Head TV translator as a signal source. The antenna appears 'useful' well above and below the design range. No

Once the feed VSWR has been assessed a new prototype will be constructed out of hobby store brass tube and box stock. The pattern and bandwidth seem excellent so far, so only the matching really needs validation/tuning. The extra expense of the brass material may not be worthwhile, the cheap (but somewhat easily bent) wire is doing an excellent job.

6 comments.

Updates

2009-01-10: Mathias Katzar Builds One
: Mathias Katzar builds an all-brass UHF Log-Periodic antenna.

2003-04-14: Tjerk Schuringa PE9ZZ writes

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search

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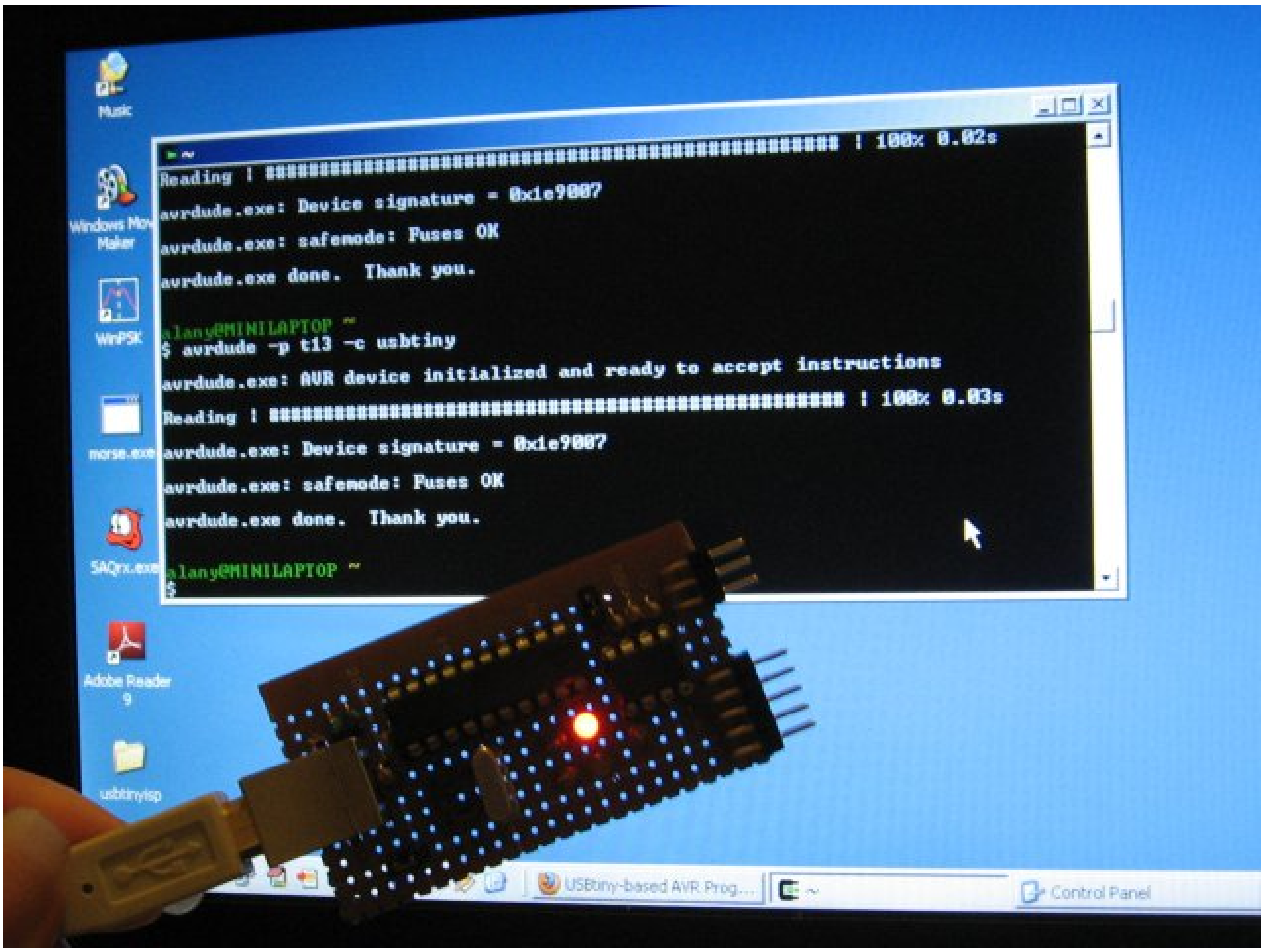
USBtinyISP Programmer

2009-12-27

The recent blinkenlight projects have giving me a need for a AVR programmer that will work with my Win32 based laptop so I can fiddle with their scripting in place (especially the larger tree project which just won't fit in the attic lab). I've been meaning to play with WinAVR anyway, it is handy to have a Win32 setup for working with AVRs, especially on the road.



The project is a simple doughnut board implementation of a variant of the USBtinyISP and USBtiny projects.

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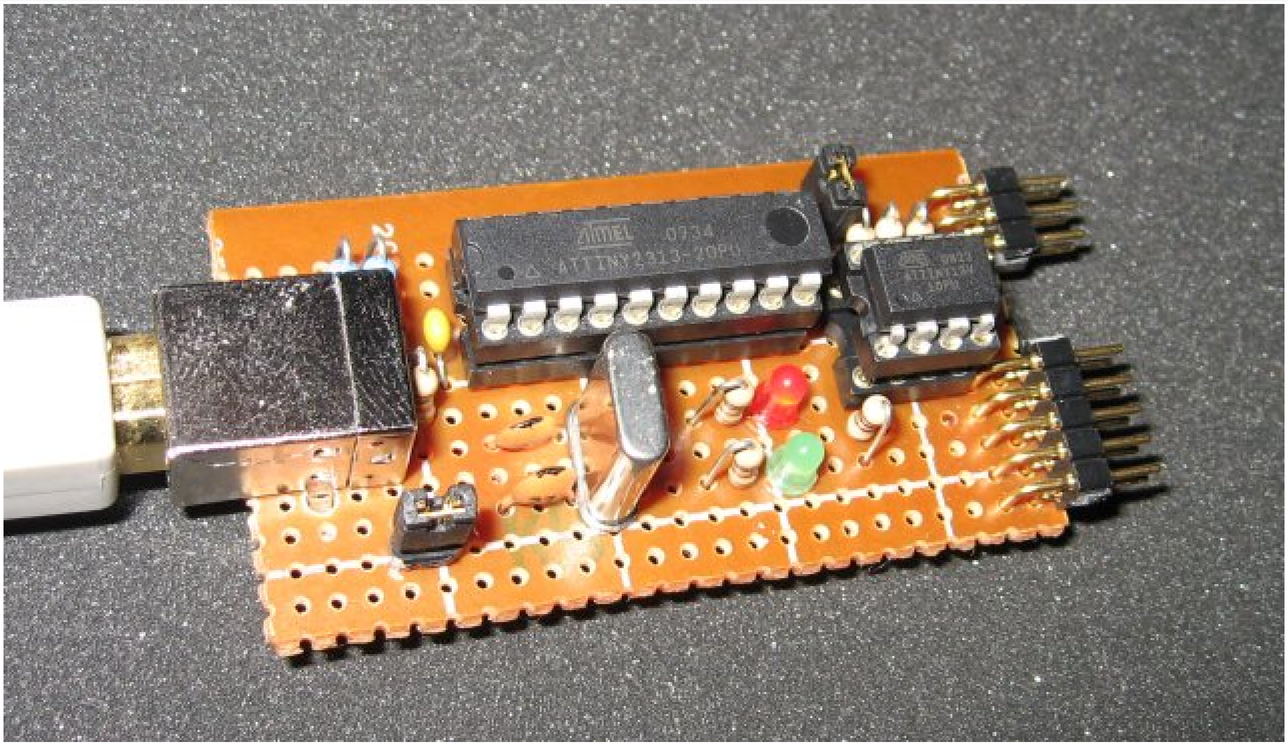
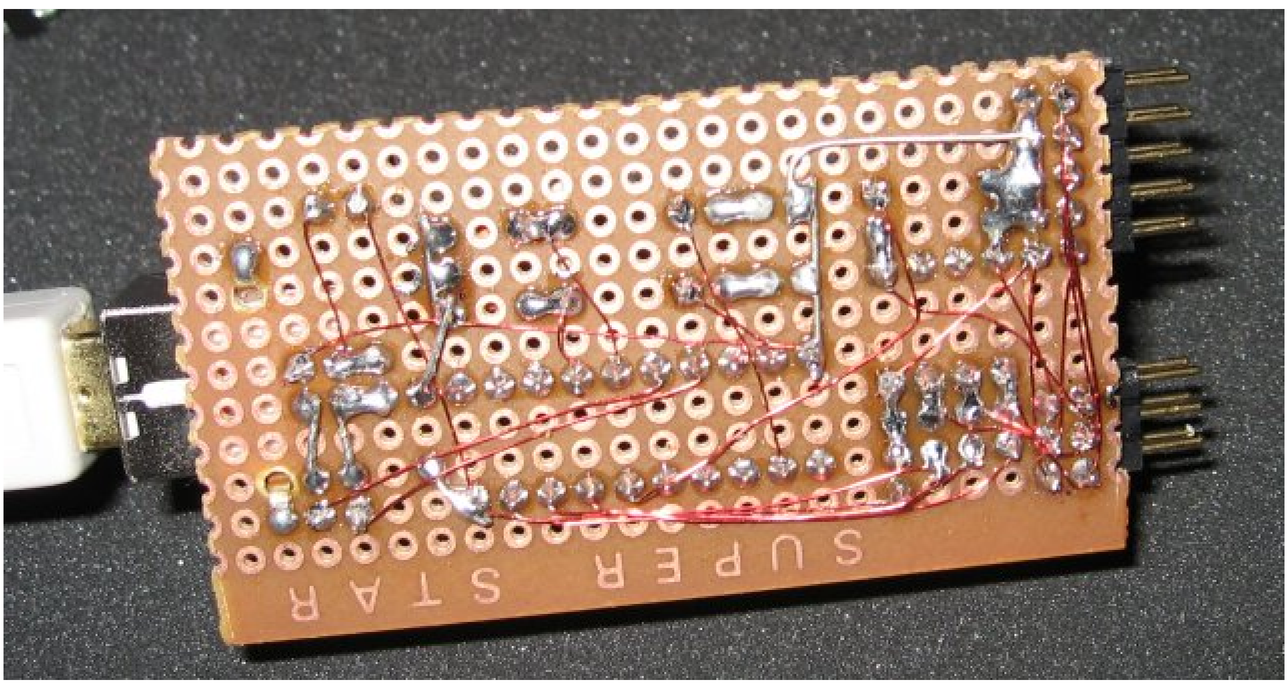


The wiring pencil made quick work of assembling the circuit. I used my current parallel port programmer to program the Atmel ATtiny2313. I left out the 3v3 clamping zeners as I did not have them in the junkbox, but put 100 Ω resistors in series with D+/D-, this seems to work with my USB ports. I'll likely add them when I get some to keep the signal lines in-spec.



I did not bother to implement the "programmer programming" header option via the ISP header that the USBtinyISP has. I did implement the power control jumpers, letting the programmer run off the external circuit or vice versa. I added protection resistors to all the ISP lines for robustness. Mine also has a 8-pin DIP socket on the board for my current programming ZIF socket adapter (or direct connection of smaller devices) in addition to the standard 6-pin and 10-pin ISP headers. Unlike the original USBtiny project I did not implement a full parallel port D25 (although that is quite tempting as I have many parallel port projects that are deprecated now due to the obsolescence of the parallel port).

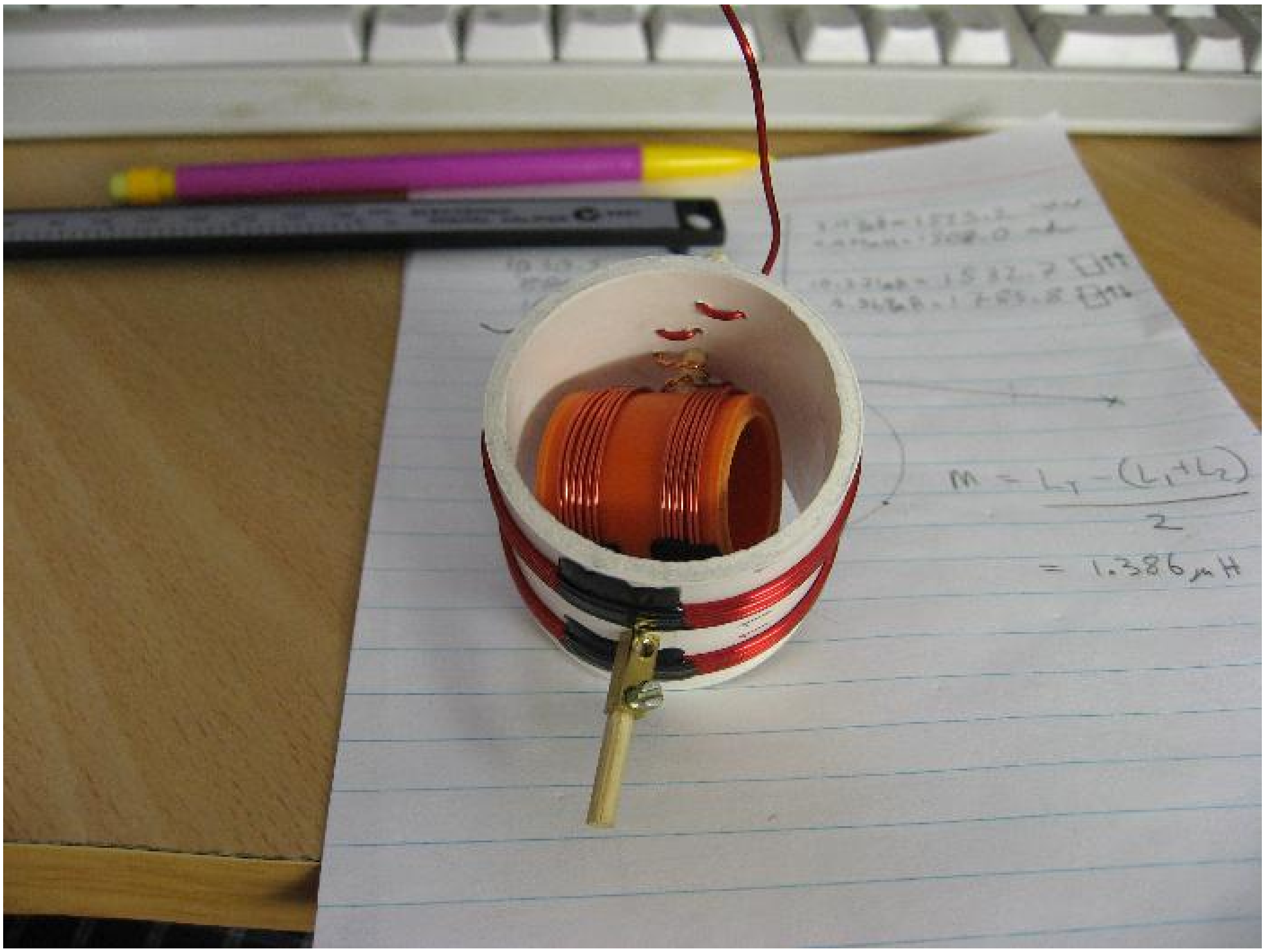
Naturally the device works fine under Linux too. In fact it was easier to get working under Linux than Windows.

1 comment.

Variometer Prototype

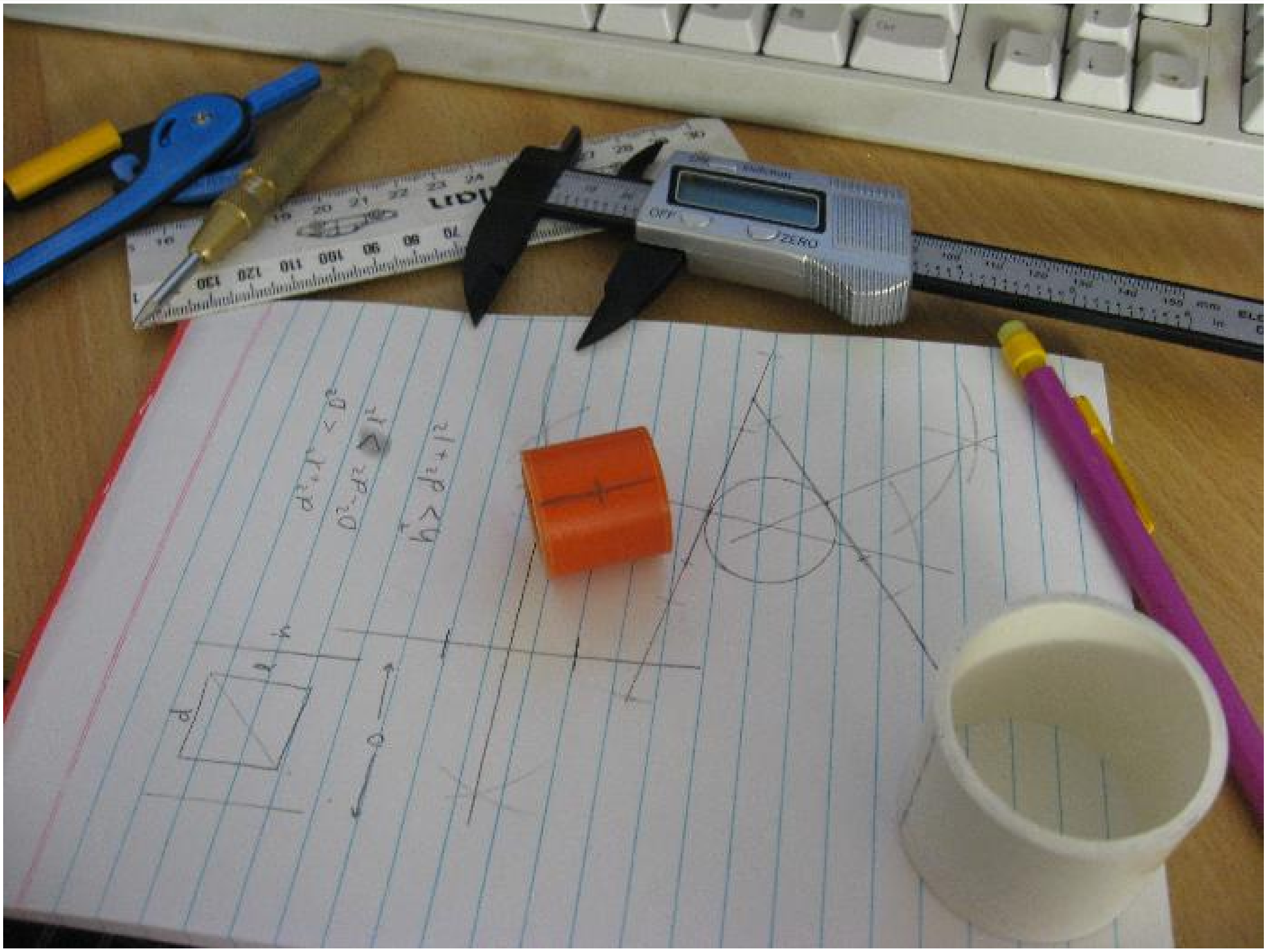
2009-01-29

Apart from lash-ups with inductors on the bench I've never built a permanent, mechanically robust Variometer before. It has been a long-time interest though, both as a bench variable inductance tool and for practical uses in RF circuits - especially antenna matching.

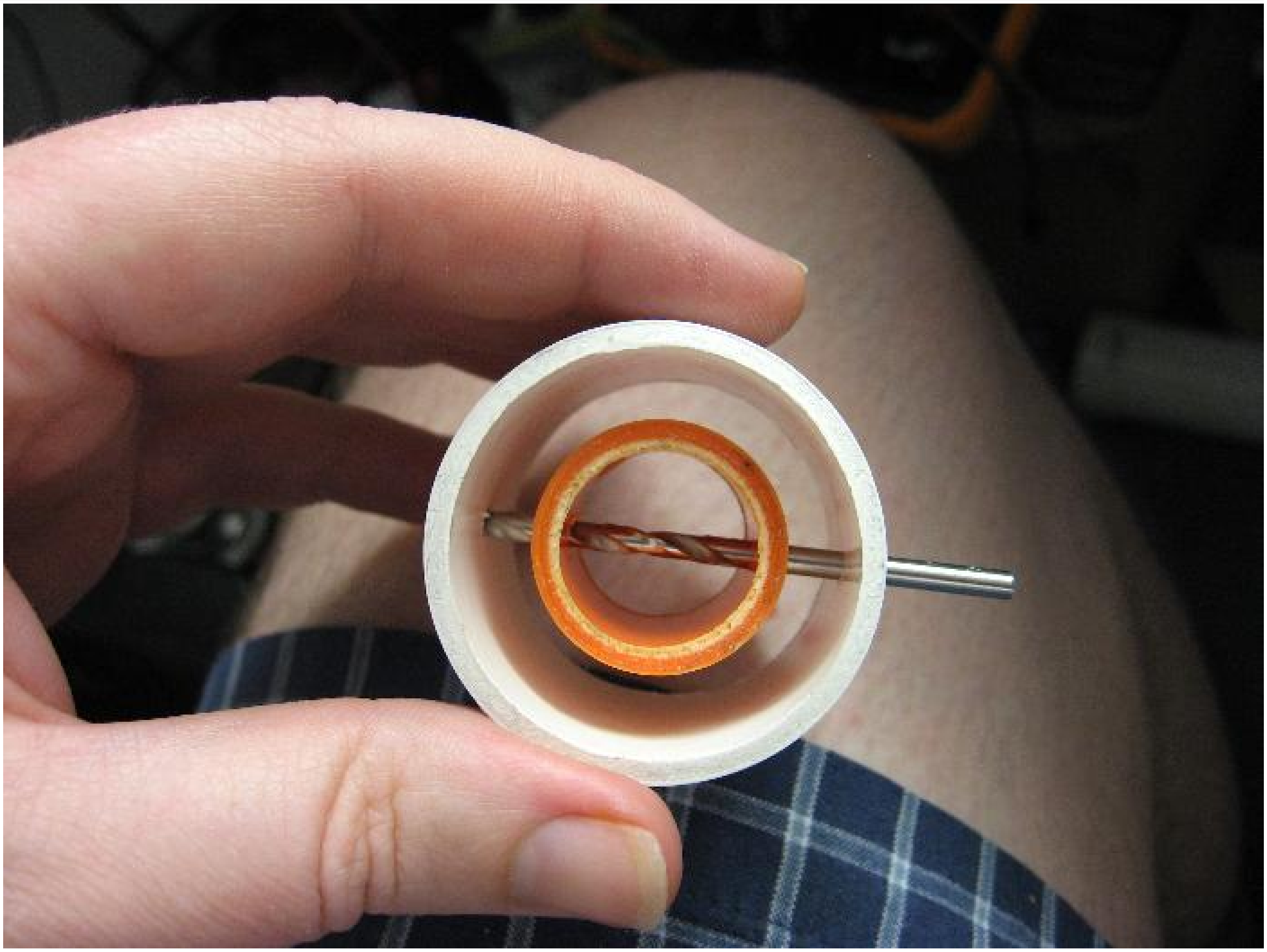


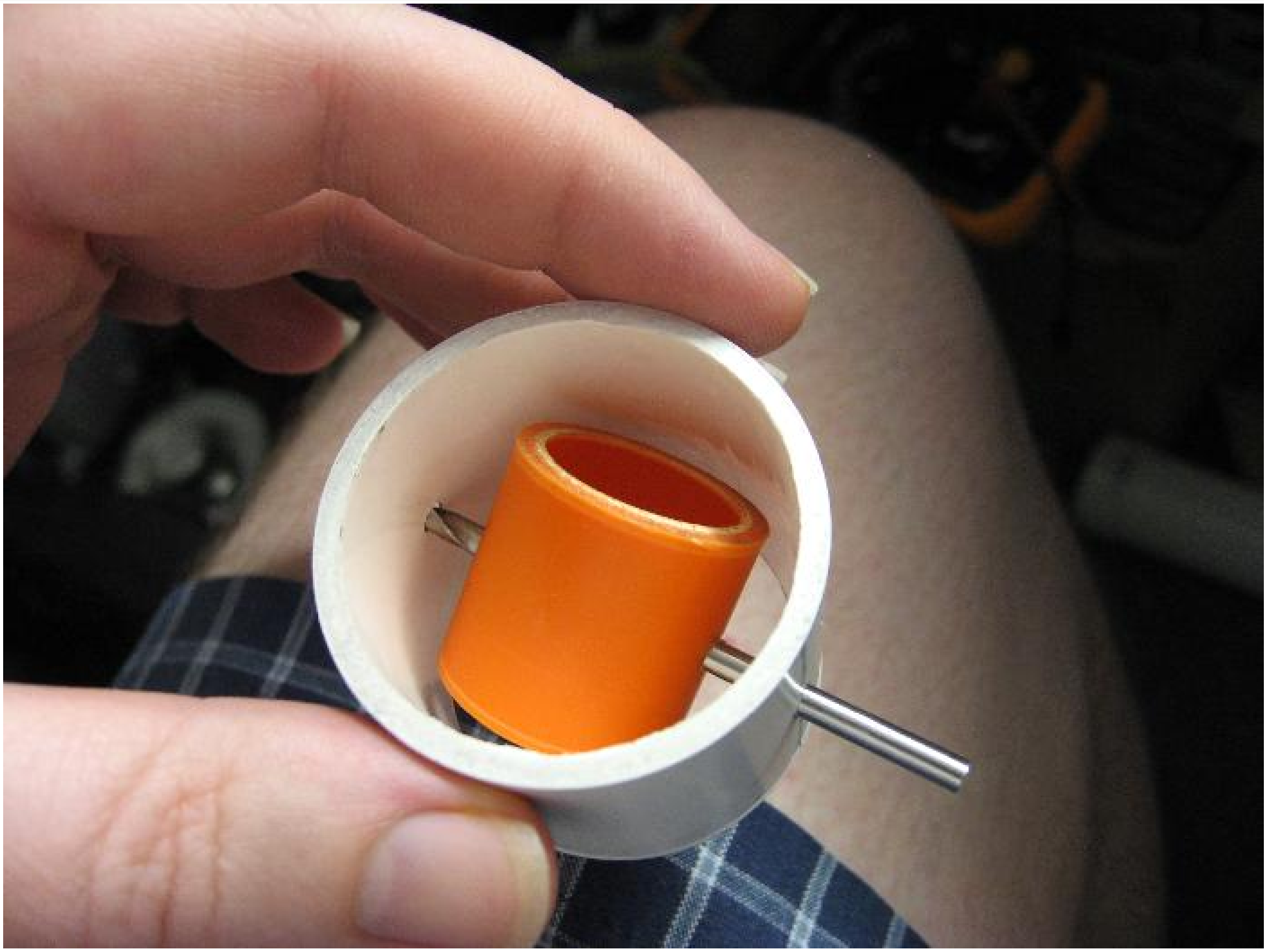
The Variometer relies on varying the mutual inductance between two coaxial solenoid inductors. This allows an inductance range of 4 times the mutual inductance, generally resulting in a 2:1 range of inductance/reactance for the finished device. The coupling of the inductors is varied by rotating one of the inductors with respect to the other. Rotation through a complete 180 degrees allows mutual inductance sign reverse (phase inversion) giving the full 4 times the mutual inductance range, as Ltotal = L1 + L2 + 2*Lm. Uncoupled, the inductors in series would total just L1 + L2 as per normal circuit theory, but their mutual coupling gives rise to the Lm term. Lm can be negative if the magnetic coupling is anti-phase, which like a capacitance can cancel the normally additive inductance.

I started construction by drawing a sketch and doing the maths to determine the geometrical limits on the inner inductor to allow rotation within the outer one. If the ID of the outer coil form is "D", the OD of the inner coil (coil + form) is "d", and the height of the inner coil form is "l", then this inequality must be met to allow rotation: d^2 + l^2 < D^2, which implies the inner former length can't exceed sqrt(D^2 - d^2). Similarly, if you want the inner coil to not poke out past the ends of the outer former (so it can be end mounted for example), then the height "h" of

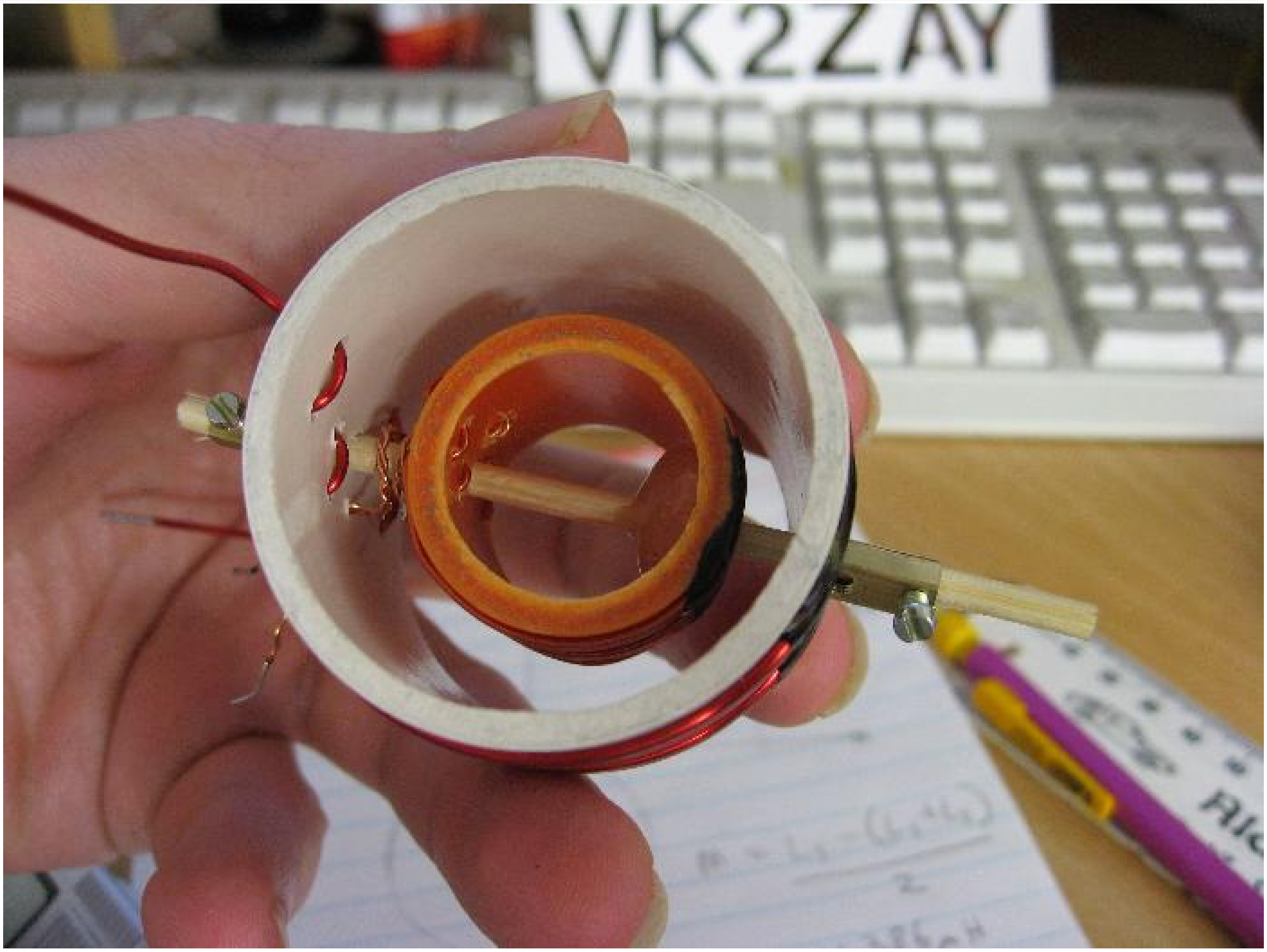


Some 25 mm PVC conduit was selected for the inner coil form, along with 38 mm ID PVC water pipe this constrained the inner coil form hight to be less than 28 mm, I chose 25 mm to give it a little bit of play. The "square" inner coil form constrained the outer coil form height to exceed 36 mm for bench-mountable niceness, so I picked 38 mm and cut up the tubes with a pipe cutter. Some rather inelegant geometrical constructions later to find the centres of the tube walls in both directions and the pipes were drilled.





Some 1.3 mm holes were drilled for securing the coil turns and the coils wound. 710 um wire was used for the inner coil, 12 turns total, 6 either side of the rotation axle. For the outer coil 5 turns each side for a total of 10 with 1 mm wire. Some liquid electrical tape was used to hold the windings of both coils in place. Some twisted-pair of 500 um wire coiled around the axle brought out the inner coil connections in a flexible manner (but I have my doubts about the long-term robustness of this arrangement, multi-strand wire would be better where the flexing occurs). The axle was formed by a 3 mm bamboo kebab stick. After trial assembly the rotor was fixed to the axle with hot-melt glue and the centring assured using brass chocolate-bar connector inserts secured over the axle as it exits the outer coil form.



The outer coil measures 4.473 uH. The inner 3.127 uH. In phase they total 10.371 uH and anti-phase 4.869 uH. The matching mutual inductance Lm = [Ltotal - (L1 + L2)] / 2 is 1.386 uH. The coupling coefficient k = Lm/sqrt(L1*L2) is 0.371. The measured "range" of 5.5 uH closely agrees with the theoretical 4*Lm figure of 5.542 uH. I was also surprised by the extremely good agreement of the measured figures with the calculator on this [excellent variometer page]. If you punch in the geometry of my device the figures it outputs are very close indeed, within a few percent. It seems to slightly over-estimate the Lm, but not enough to be a problem in practice.

This "5-10 uH" variable inductor might become my long desired "L-jig" to match the other [R and C ones], or it might become the interpolating inductor along with a fixed taped inductor in an L network matching unit. It's unfortunately high 5 uH inductance limits the HF response of such a matcher, having about j943 Ohms impedance at 30 MHz, however this could be tuned-out with a series capacitor capable of tuning below 5.6 pF. Designing a tapped inductor with ~ 10 uH steps for 90-100 uH would let me tune a 23 pF vertical at minimum of 80 metres. I know the 3 metre vertical on my balcony takes less than 60 uH to tune it (ie 32-33 pF of capacitance), so even just a 50 uH fixed inductor tapped 5 times plus this inductor could tune out its capacitance across HF as long as I had a way to switch in a series variable capacitance on the last tap (Variometer only).

7 comments.

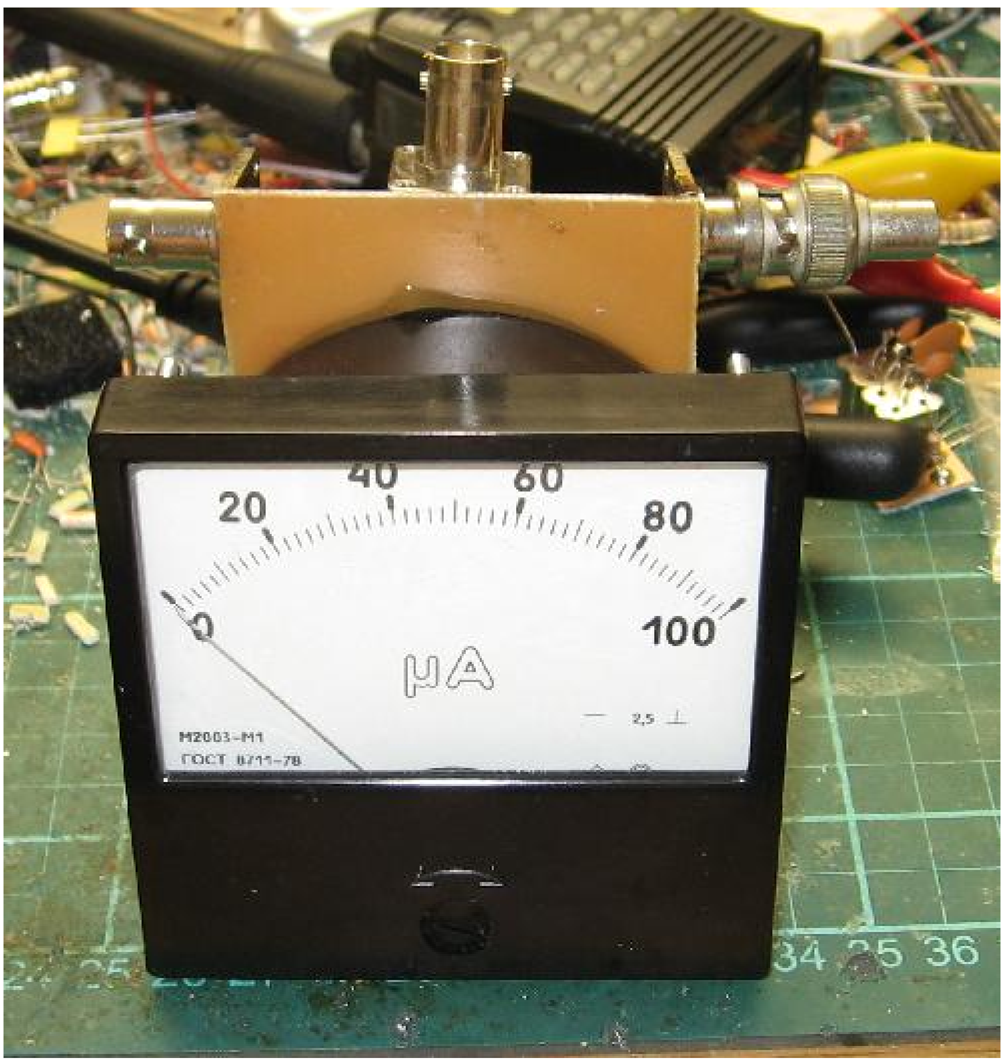
VHF Impedance Bridge

2007-01-13

I've been trying to get into the 147.0 ARNSW repeater, so I can join their homebrew group's net on some Tuesdays of the month. Unfortunately my old FT-415 just can't make the trip barefoot, so I wanted to make an antenna that I could wander up the street with and perhaps get in...

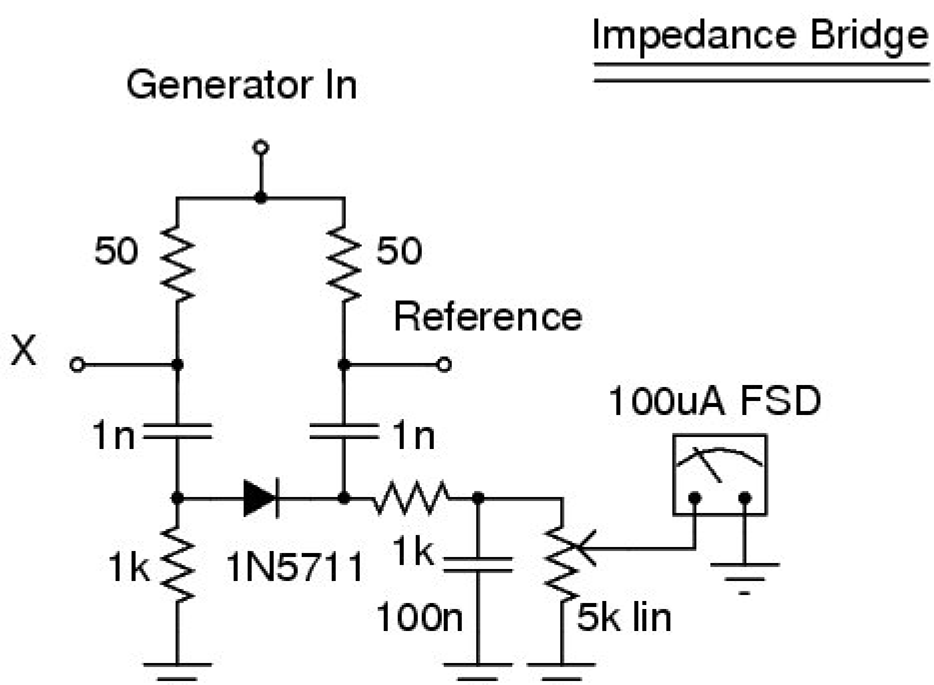
I've been meaning to give the "flower pot antenna" a go, so I wrote to John Bishop VK2ZOI and he was kind enough to send me his articles which include dimensions and all the information needed to make 6 m, 2 m, 70 cm and dual-band 2 m/70 cm antennas. All I needed was a way to assess the VSWR and prove I'd constructed them correctly... I had to build myself some kind of SWR detector for 2 metres.

In the past, I've used my trusty Z-bridge on HF, but at 2 meters it gave me non-zero returns into a known-good dummy load - not a good sign. This project is another Z-bridge, direct from the pages of EMRFD (page 7.24, diagram 7.43). It is claimed to operate into the UHF region, I haven't proved that or really expect it with the sub-optimal resistors I used, however it is perfectly flat to beyond 200 MHz according to my measurements.



I threw it together in about 1 hour - most of that time was trying to get the damn BNC plugs to tin, so I could solder them direct to the board. Some filing and lots of heat did the trick eventually. The meter is from KW-TUBES on eBay, I have several left, they are perfect for this kind of project.

At maximum sensitivity even my "loadstar" signal generator can make a deflection, so QRP use is fine. With the resistors I used it should handle a few watts.



For the 2 metre antenna project it worked perfectly, allowing me to trim my "flower pot" to a pretty good match.

the repeater... More work to be done here, QRO will be needed I suspect. I might have a go at making a helical resonator to null the pager quite close to my QTH, or even a BPF for the band, but that is probably more plumbing than the old HT is actually worth.

3 comments.

Attachments

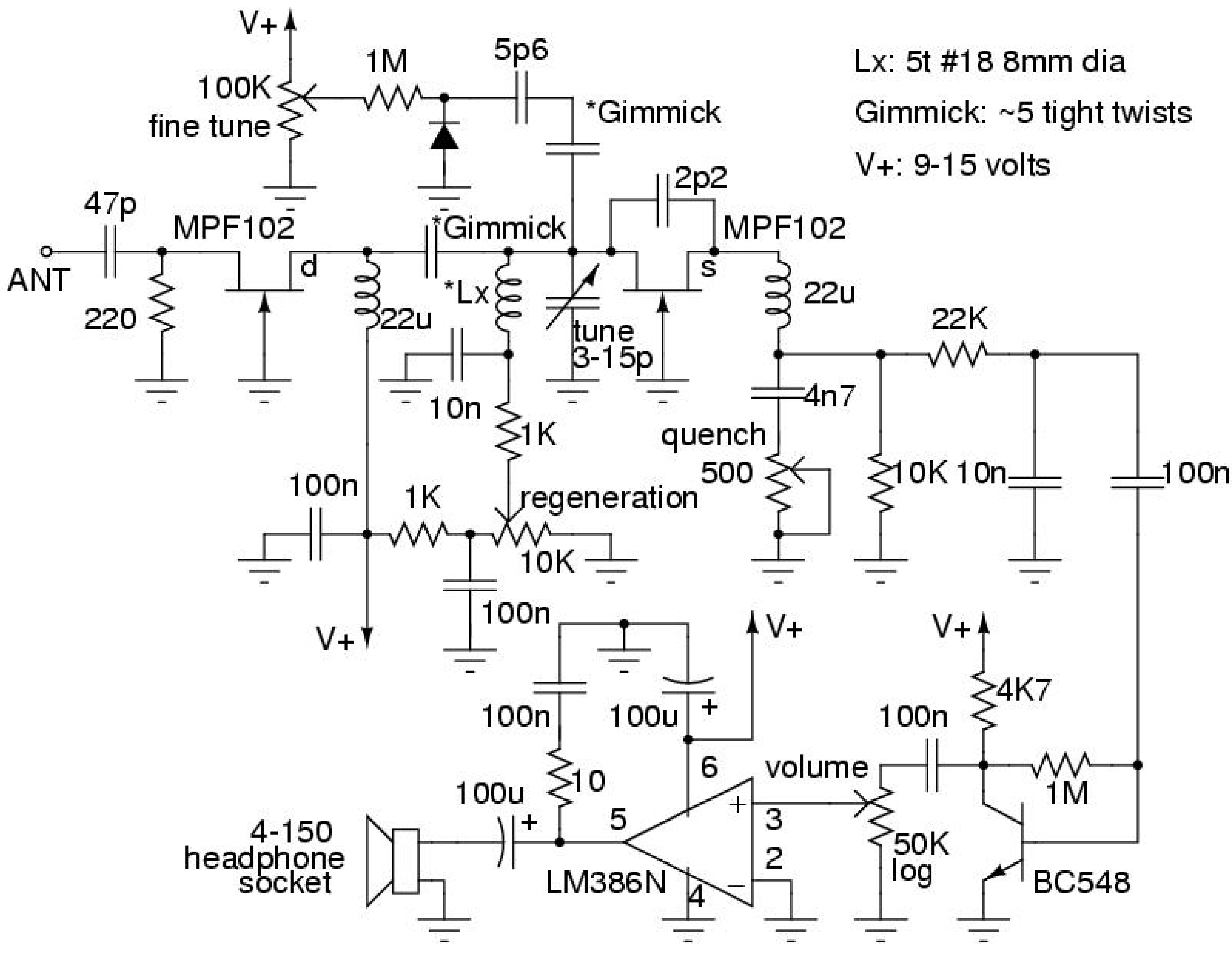
title	type	size
Circuit Diagram Source	application/postscript	11.993 kbytes

VHF Super-Regenerative Receiver

2002-03-07

I have started straight with the circuit out of the ARRL handbook, by Charles Kitchen N1TEV. I didn't have a 6v8 zener, or a few other part values, so I had to substitute a bit.

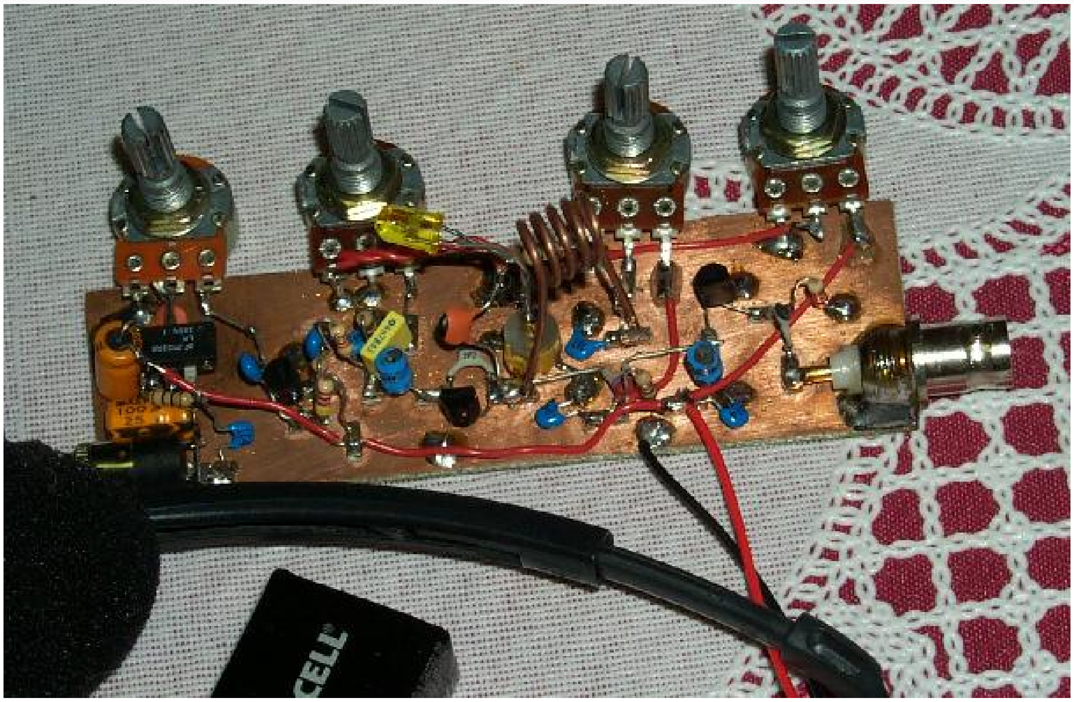
Unlike Charles' original circuit I found an audio pre-amp was needed to get sufficient AF gain so the 386 could actually be driven into saturation at full volume. I did have the 386 in its lowest gain configuration (nothing between pins 1 and 8), but the audio was still too weak when I tried it with a gain of 200. The single transistor pre-amp is collector-base feedback biased, which gives high gain, moderate noise, great stability and a good-enough frequency response, it isn't the best topology but it has a low parts count. I used 100n coupling caps in the audio path because I have a huge quantity of them, not because they are a good value choice. That said, the bass response is still quite acceptable, and the monolithic devices are much cheaper/smaller than electros.



Construction was an organic affair, the unit was built as a prototype, I never intended to finish it off and use it as much as I now do. I listen to FM broadcast radio stations with it almost every night, I even take it to work and listen to the radio there some days.

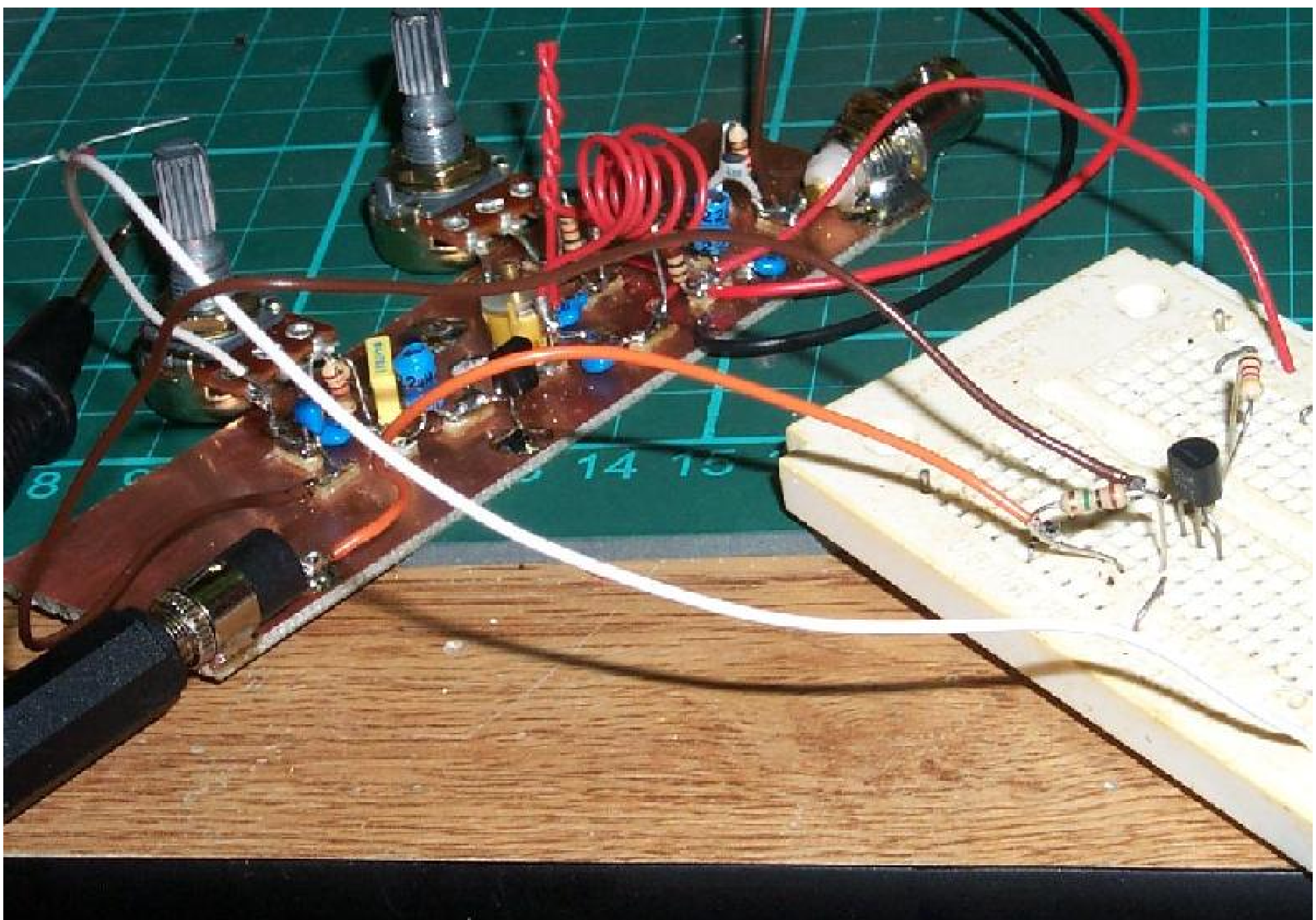
Note the main tuning coil, it is made from the thick 1.5mm Cu core of house mains wiring. Such wire is cheap, about $1/metre, but contains 2 quite solid conductors, and one stranded (earth) conductor which can be unravelled to give 8 thinner solid wires, or used as-is. The coil must be kept high off the board to reduce stray capacitance for good performance. In hindsight, my choice to use a slab of unetched circuit board for the prototype limits its performance severely. However, it is mechanically robust and forms a low Z ground plain which helps stabilize the receiver.

The audio power amp has a touch of instability operating into higher Z loads with long leads (ie headphones). At high volume levels it can groan. A 10 ohm resistor in its power supply decoupling circuit should fix this, but I haven't bothered to add one yet, I

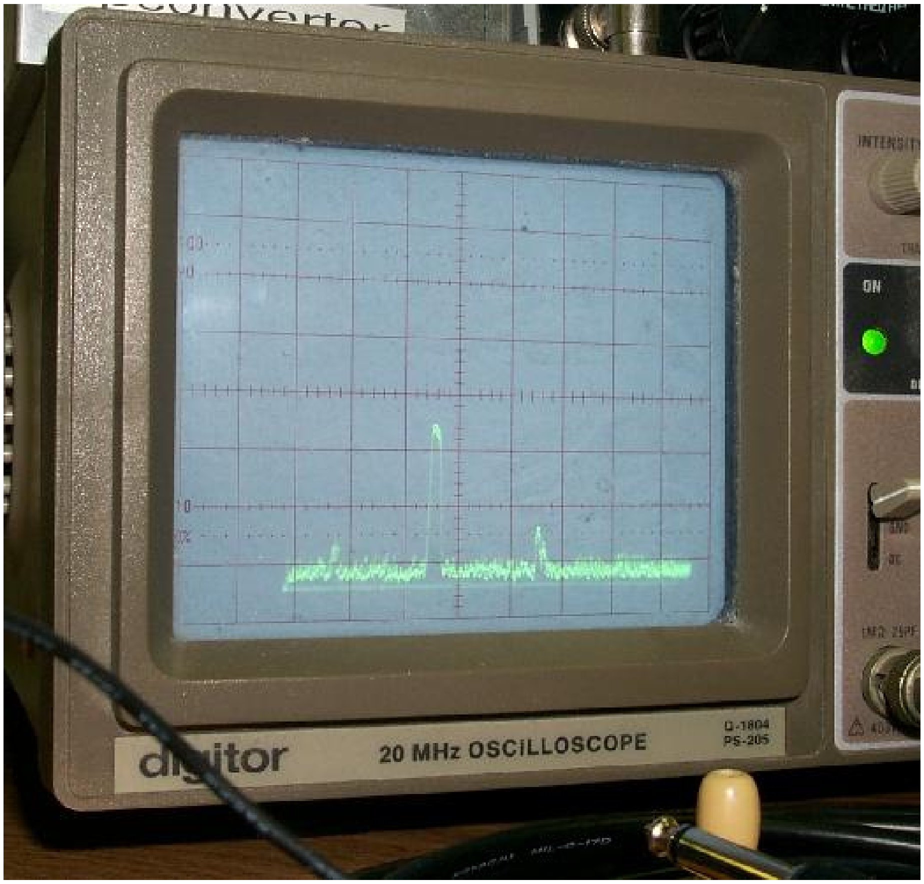


Here is an image of much earlier in the construction, the audio stages were built last (unusual), the audio pre-amp is on the breadboard, tacked to the rest of the circuit by some hook-up wire. There is no volume or fine-tune control at this stage, and the inter-stage coupling is a gimmick (later replaced by a 1p cap).

The coil was attached with IC socket pins, which allowed trying many geometries for performance and to play with different VHF frequency ranges. The thin solid hook-up wire used for the main coil was very poor for its performance, the losses being quite high, often the unit would refuse to oscillate at all unless the supply voltage was raised to 15v and the drain-source feedback cap tweaked.

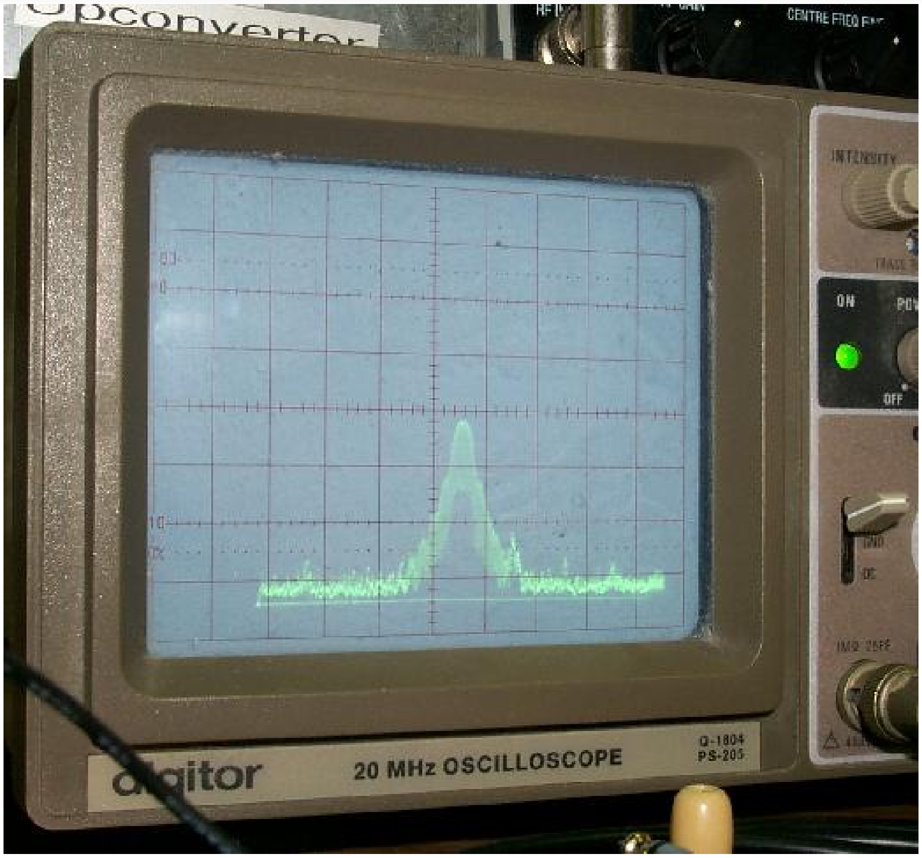


Here is a spectrogram of the receiver in regenerative oscillation. There is no quenching here, it is just making a pure RF sine wave, there is only modest amplification in this mode (there would be more if the regeneration was backed off to the edge of oscillation, but then there would be nothing to see), the selectivity is enormous, you can beat carriers of FM stations, even an AM signal generator's 1.5kHz sidebands are resolved and can be beat separately without a lot of heterodyne from the other 2 line frequencies (carrier and other sideband) in the audio passband, this is straining the stability of the receiver though, the fine tune control is a must to be able to keep up with the thermal drift from your breath.



Here is a spectrogram of the receiver in super-regenerative oscillation. The quenching rate is about 120kHz, the waveform looks rather sawtooth like, but has smooth edges. The spectrum analyser's IF bandwidth is about 100kHz, so it doesn't really resolve the quenching sidebands and their harmonics, but you can see the sinc shaped envelope of the higher harmonics due to the scan rate harmonically beating with them.

While the poor IF selectivity of my SA has smudged the details it appears that the main oscillation is actually FMed as well as AMed by the quenching oscillation. It makes sense, the operating point (and hence the drain capacitance) of the FET is being pulled around by the quenching oscillation voltage on the source. This makes it much more complex to say what is **really** going on during the FM demodulation. The slope can't be too flat, and could be quite complex. I would like to investigate this mathematically in the future.


Upconverter
CENTRE FREQ
INTENSITY
ON
OFF
GND
DC
digitor
20 MHz OSCILLOSCOPE
Q-1804
PS-205

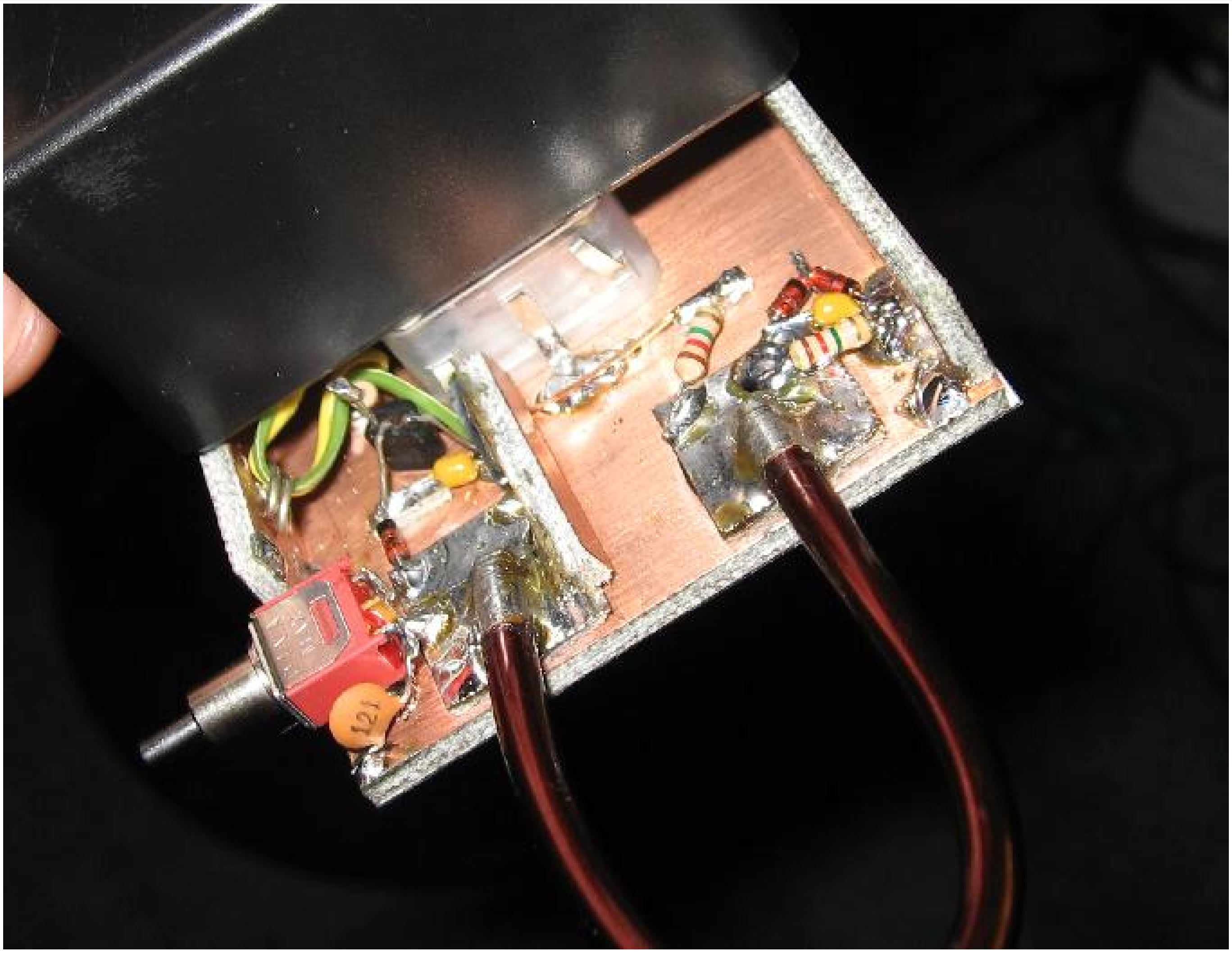
4 comments.

VHF Wavemeter

2008-10-19

Very similar to the HF version, just designed around a hairpin of 4 mm copper wire instead of a solenoidal coil. The ~60 pF gang of the polyvaricon is used alone to resonate the hairpin. An additional 120 pF of capacitance can be switched in parallel to implement the lower band.

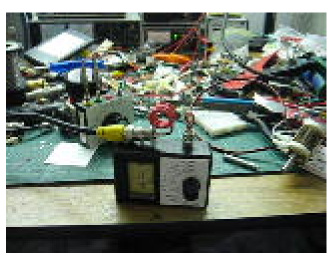
Construction is upon a square slab of rather thick PCB material that Kevin VK2ZKB was kind enough to give me for my experiments. Also from Kevin came the smaller pieces of PCB that the hairpin is soldered to. He has tooling to make short-work of cutting up PCB, a task for which I keep promising myself that I'll purchase some better equipment for at some point. He and I have been discussing cutting thin strips of PCB the right geometry to implement strip lines for higher frequency work. It took a lot of heat to solder that thick chunk of copper to the PCB, challenging the super-glue used to attach the pads to the main board.



The circuit is otherwise identical to the HF instrument, power supply is the same 3V lithium cell inside the black plastic box which also houses the meter. There is no off-switch or any means provided to turn it off. It tunes 49 - 57 MHz for 6 metre coverage, and 76 - beyond 150 MHz for FM broadcast band and 2 metre coverage.

I use it mainly as a selective signal strength meter looking for stray currents in antennas. It isn't a very useful instrument in terms of absolute frequency resolution, but relative RF power and frequency ball-parking it works fine for.

I successfully made a coil for the HF meter which covers a similar range but with somewhat less sensitivity. Here is a video of me demonstrating mutual inductance coupling between tuned circuits at 2 metres using the older wavemeter.



Resonator Coupling Demonstration
(8.102 Mbytes)

I must admit I kinda like the HF unit better, it is a neater package and is more flexible, but this fixed-coil wavemeter covers the FM broadcast band and 6 metres with better bandspread. It would be excellent for people making FM wireless microphones (bugs) for both working out their rough TX frequency and tuning them up for best output. I wish I had made one this sensitive back in the days when I was an FM broadcast pirate. I did build a VHF wavemeter long ago, but it was a passive one and needed a fair signal for a reasonable deflection, I also then lacked the instruments to calibrate it properly.

Alan's Lab

me and my geeky hobbies

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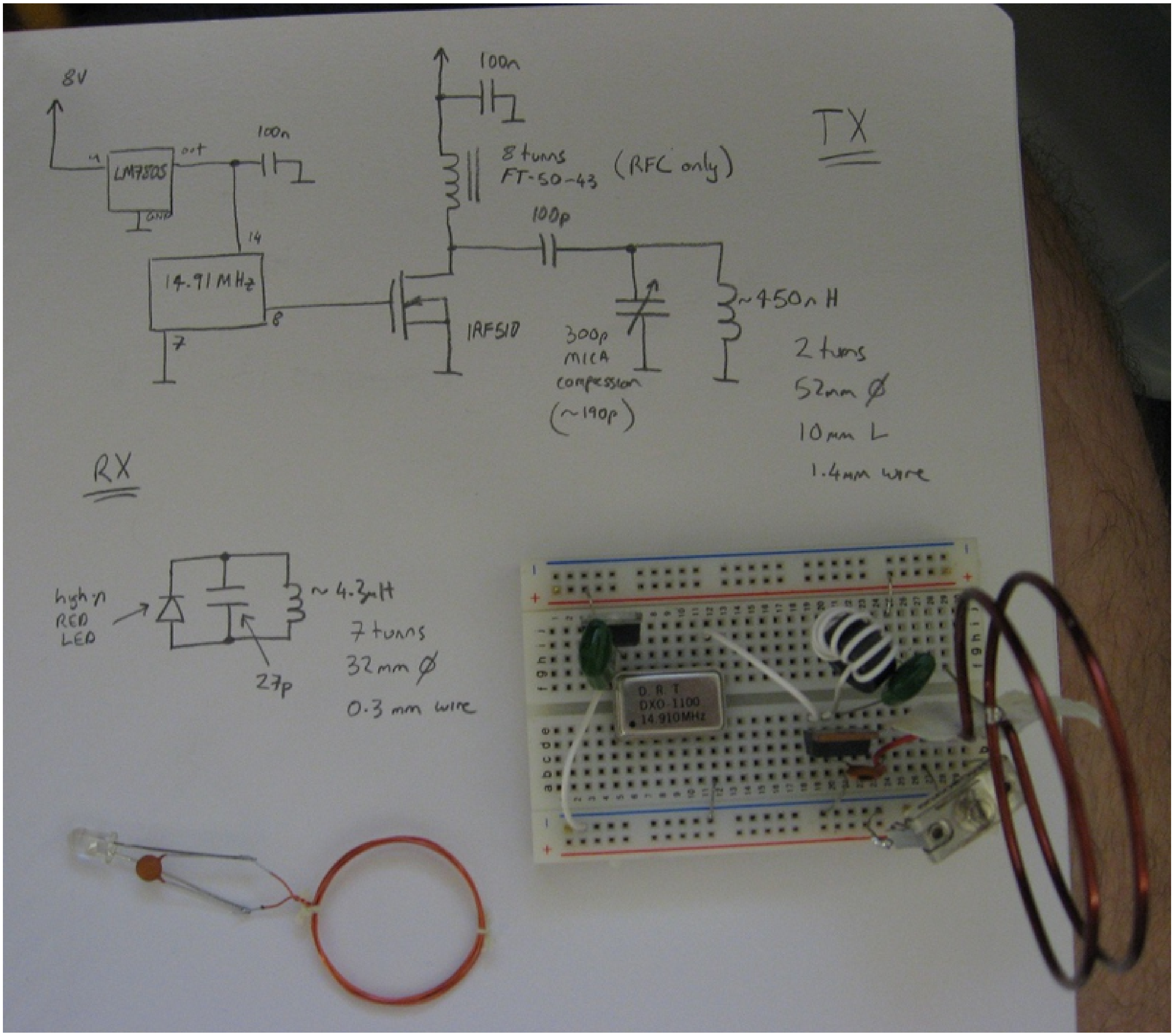
Wireless Power Demo Circuit

2011-04-26

A lot of people have been asking me for the circuit of the demonstration TX I used in the video, so here it is:



This is *not* an efficient design and is meant as a demonstration only. The compression trimmer should be fairly high quality, but as the demo was on a solderless breadboard perhaps any old junk trimmer would work OK? The IRF510 is hardly the best device for this service. There should *really* be a gate-source resistor on the MOSFET, if the drive disappears it will probably smoke, the drive probably isn't within spec either.

The tuning is quite sharp. Peak the trimmer for best range using the LED receiver. You may need to tweak the 27 pF capacitor in the RX coil to match your particular coil inductance, use a trimmer if you prefer.

Other frequencies for the canned TTL oscillator module should work fine if you adjust the tuned circuits appropriately. I used my resonance calculator to get ballpark values then tweaked from there. It is also helpful if you can measure inductance with some precision, I used my Carver-style LC measurement device for that.

If you were designing for high efficiency I'd suggest a class-E amplifier approach, with link coupling to an otherwise completely floating tank circuit. The link winding size/angle could be adjusted WRT the tank to adjust the coupling to optimise matching for

XHTML | CSS | CSS toggle

best efficiency into whatever load is reflected. It would be useful if you could predict/measure the impedance seen to optimise the power amplifier design, but an L or Pi network and standard antenna matching techniques can be used.

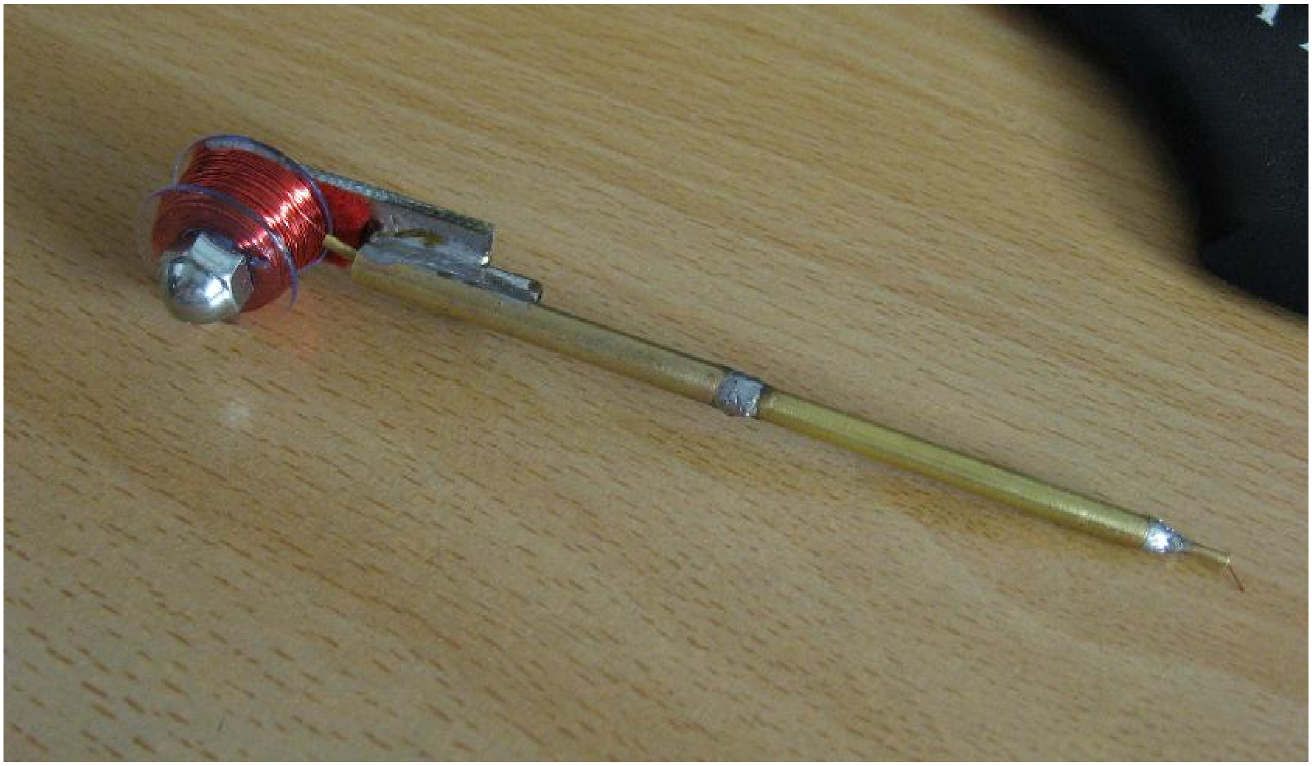
29 comments.

Parent article: Wireless Power Experiments.

Wiring Pencil

2009-02-15

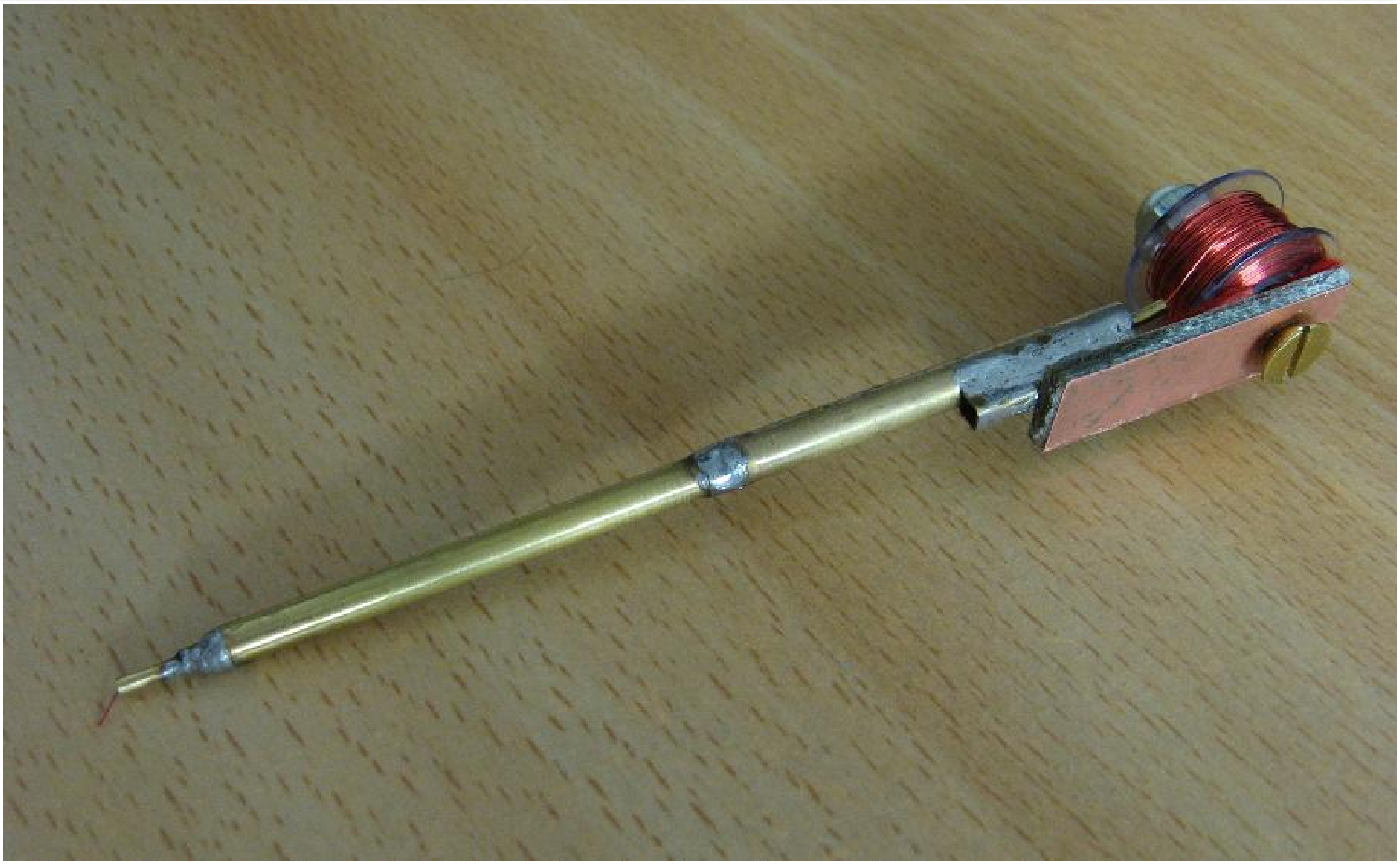
Verowire and Road Runner pens/pencils are not available in Australia (at least as far as I've been able to find), so I've always built digital prototype circuits point to point with magnet wire by hand (ie juggling a spool of urethane enamel magnet wire, tweezers, side cutters and the soldering iron). Today I had to build a relatively simple interface board for LED matrix devices, but in frustration after dropping the spool and tangling the wire I finally got around to building a proper wiring pencil.



Some brass tubing from a hobby store bulk-pack was used. The pack came from Hobby Co and while moderately expensive contained a great variety of different sizes, all about 100 mm long. The smallest ID tube available was about 0.8 mm (allowing comfortable use of 125 um, 200 um and 500 um wire depending on the application), this was telescoped with several other pieces to build the barrel of the pencil. Some channel stock was used to attach the pencil barrel to a rectangle of PCB material which supports the sewing machine bobbin containing the wire. Electrical solder holds the works together - I had all the parts except the brass tubes sitting in the pile of junk of my desk. You could no doubt build something similar using a discarded writing pen, perhaps with a sports-ball inflation needle.

Some felt was fixed to the PCB material to facilitate variable tension; the spool axle is a brass machine screw which is tapped into the thick PCB material, a cap nut is tightened onto the bolt and the entire bolt moved in or out of the PCB to control the friction between the bobbin and the felt. This works quite nicely to control the flow of wire.

The bobbin was filled with wire by attaching it to my electric drill and running on enough wire to fill it from a larger spool. (BTW: a 6.5 mm audio jack just happens to be an excellent friction fit with the ~ 1/4" centre of the sewing machine bobbin. No doubt a bolt with washers would be a safer and more conventional choice - or perhaps a bobbin winder machine if you have access to one.)



I am yet to find a local source for something like the wire management combs both commercial prototyping systems use. It is said that the self-fluxing wire the commercial guys offer is easier to work with than common UCW - dunno, never used it. The UCW wire is quite easy to tin, especially the 125 um wire which tins even starting far from a cut end. I prefer the mechanical properties of 200 um wire for general purpose work, and use 500 um wire for lines carrying significant current, but I often put thicker lines in by hand anyway. You might like to have several spools (or better, complete pencils) of different colour wire, say red and green for power, amber for signal, etc.

10 comments.

Updates

2009-02-16: Solderability of Enamelled Copper Wire
    Tests of tinning various types of enamelled copper wire both from cut ends and through unbroken enamel.

The Fredbox

2007-05-26

I first heard about The G3XBM Fredbox transceiver via Solder Smoke. As soon as I saw it I just had to give it a go. It is a very simple and elegant design. Of course it offers no bells or whistles, just a fixed TX and RX frequency, and a flea-power output on TX, but it has a special charm in its simplicity and the retro usage of AM on VHF.

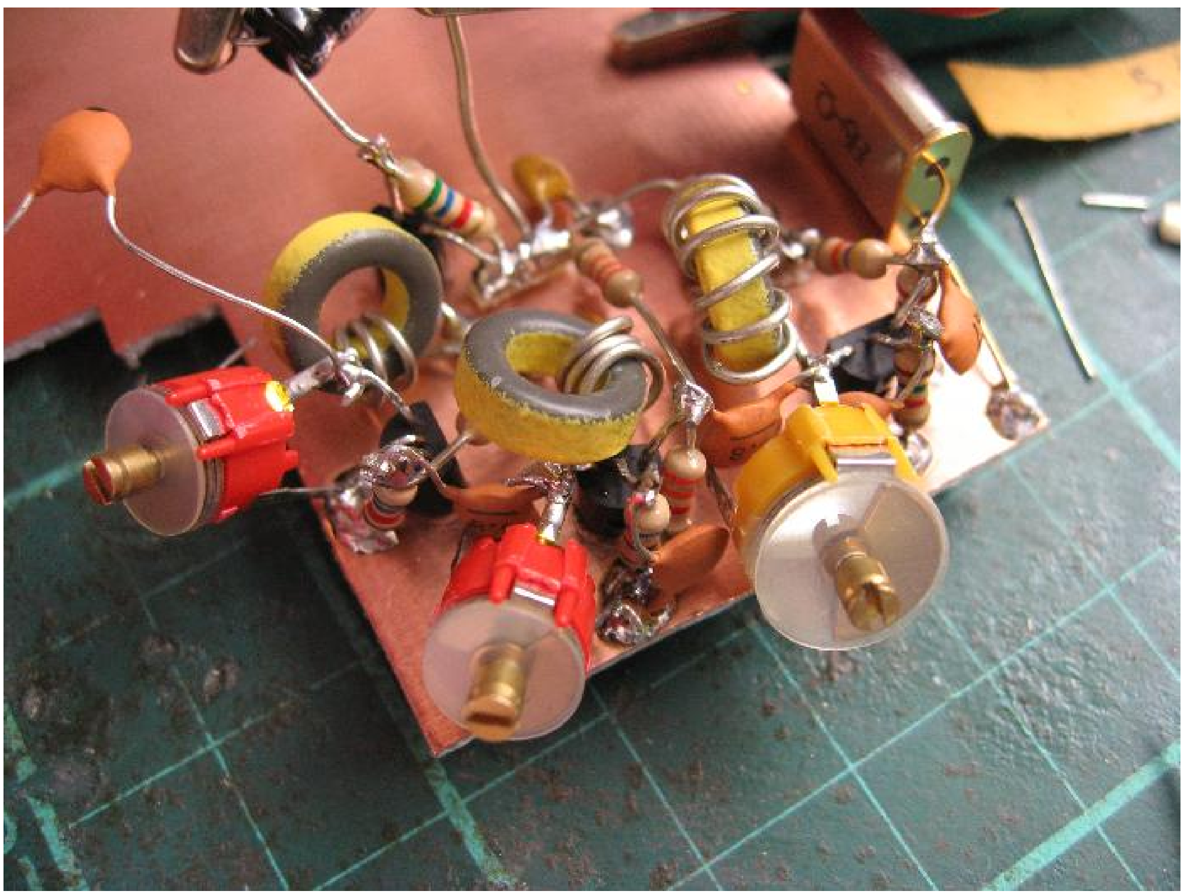
Transmitter

I built the transmitter side first. BF199s were selected as a good candidate for the RF devices, but I lacked a crystal in the range specified in the original article. Instead, I used a common 16.384 MHz crystal and redesigned the circuit to be two triplers rather than two doublers. This crystal is a common "computer" crystal, but places the TX frequency in the high-end simplex segment. This is a bit too close to the pager-splattered end of the band for my liking, and doesn't match the band-plans. For now this is OK, I'll get a custom crystal cut eventually.

I didn't use shielded cans or variable inductors for the transmit coils (as specified by the article), rather I used fixed inductances wound on T37-6 toroid cores with bare 0.71 mm tinned copper wire. My LC resonance calculator and nH inductance meter were enormously helpful in making the selection and testing of the tripler and output stage resonators. Each stage was tuned with trimmer capacitors.

It was amazingly easy to get the TX-side working, I just built each stage from the crystal to the final amp in turn, testing as I went. Each stage is well behaved and peaks nicely.

Peter VK2TPM could hear the signal at his QTH several kilometres away when I connected the half-finished TX board into my flower-pot antenna. The DC input power was about 23 mW, and no special attempt was made to match the output into the load, in fact the series trimmer in the matching network was absent at this point, just a fixed 12 pF capacitor was used for DC blocking.



Upon finishing the TX circuit I did experience a bit of RF pick-up in the microphone amplifier 2nd stage. A 1 nF capacitor to ground discouraged its RF gain and eliminated the problem. The 2nd AF amp stage is located immediately adjacent the crystal oscillator stage and was picking up RF directly. The effect was not audible, but was visible on the spectrum analyser as weak 16.384 MHz sidebands either side of the carrier. This wasn't causing feedback, just high-frequency modulation of the signal. If nothing else it proved the bandwidth of the modulator, which is perhaps a surprise considering the 100 nF decoupling on the modulated rail, however the output impedance of the series modulator emitter is so low it could deliver a few tens of mVs of HF ripple into that kind of load.

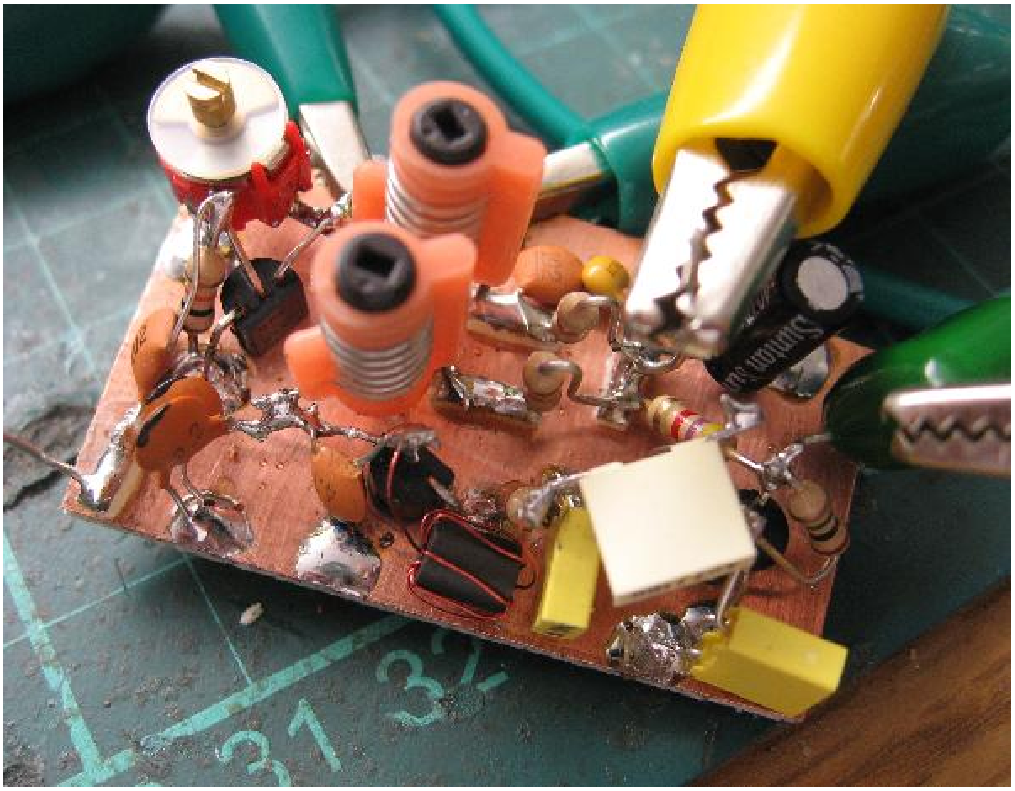
Receiver

As easy as the Transmitter was, the Receiver was hard. It fought me every inch of the way. I spent an entire day trying to work out why it was simply not super regenerating from about 130-160 MHz. It turned out to be a 10 nF decoupling capacitor on the cold-end of the detector resonator. The article specified 1 nF, and I originally intended to use this value, but I had a strip of 10 nF mono's on the bench, so I used them. At build time I did consider why 1 nF was specified in the first place, I figured it was avoid the exact problem that would befall my unit, decoupling resonance. (Lesson #1: Trust the original builder and your initial instinct.) When the unit wouldn't oscillate properly I assumed that I had damaged the capacitor on install - this is a pretty common fault, so I tested it in-place by ensuring it would shunt a HF signal (my standard decoupling cap test), it passed this test just fine. (Lesson #2: Test at the frequency of operation.)

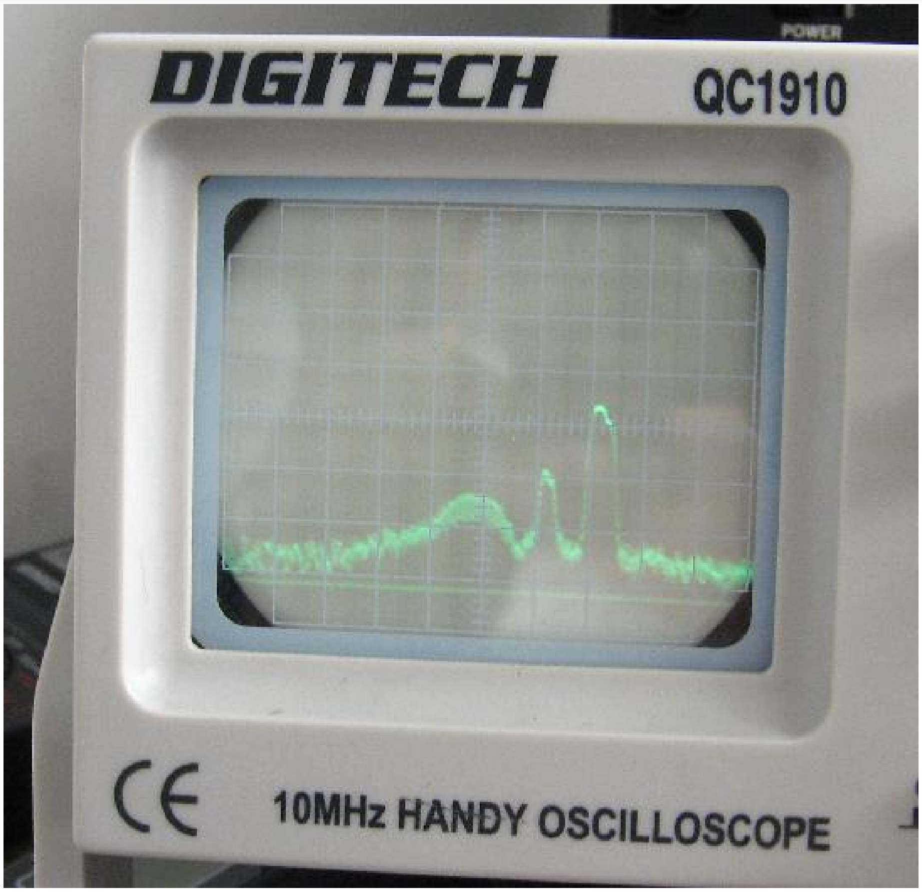
My hubris about "modern components" being superior and likely "purely capacitive" at VHF turned out to be completely wrong. It took *hours* to work it out, but eventually I determined the entire decoupling network was resonant near the operating frequency. Much foul language later and I replaced the cap with a ceramic 1 nF, with its "flashing" broken off and scraped right back to the disc to minimise the lead length. This cured the problem.

For the longest time I had assumed it was the source coil - and in fact the first source RFC I used (a molded choke) was being operated above its self-resonant frequency and prevented any oscillation at all. I replaced it with a few turns on a ferrite bead which seems just fine now.

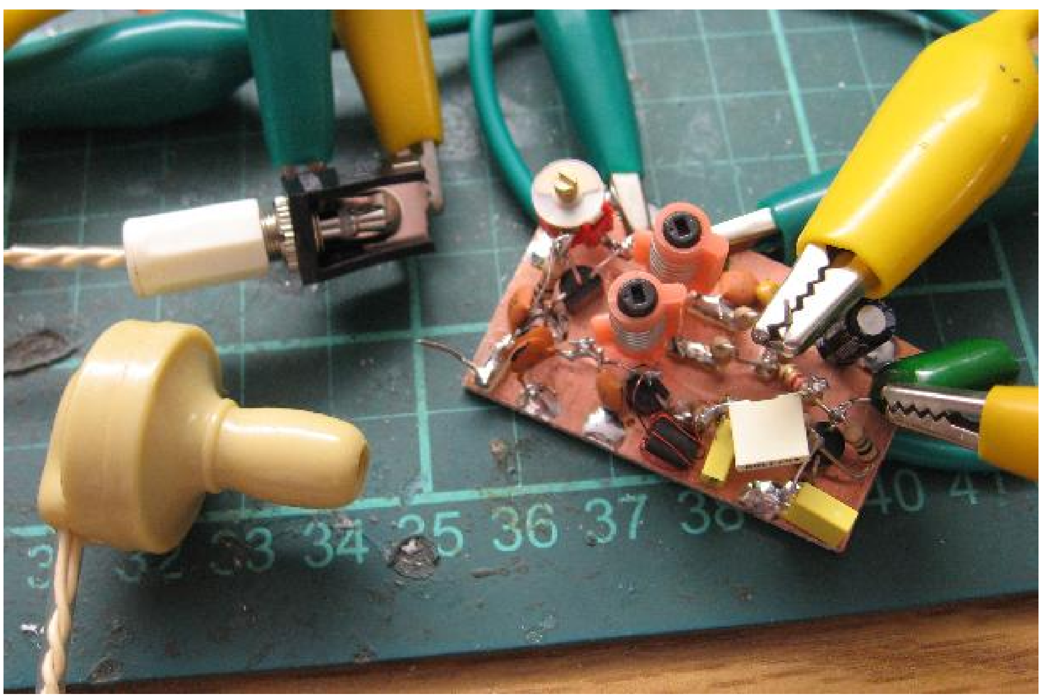
A couple of other minor annoyances/mistakes were worked through (like picking larger inductances and making the entire circuit so sensitive to stray capacitance it was a nightmare to tune - DUH!).



Eventually the unit super-regenerated right through the region of interest and the LNA stage was constructed. Initially I put the LNA drain coil too close to the detector coil and they over-coupled. This meant as I tuned through resonance on the LNA drain it would pull the detector so much it would shut down. Bugger! Moving the coils apart a little reduced this effect to acceptable levels, but the core of one still effects the other a little. I'm happy with the current coupling, and it is actually useful to help tuning the LNA resonator. As you rock it through resonance it will pull the detector, and by observing the wiggle on the spectrum analyser you can tell you've got it tuned up. The AGC action of the detector makes it hard to tune for maximum smoke otherwise, as the AF output doesn't change much at all even when the front-end isn't tuned up properly. Once you've got it nearly right you can use a weak signal to tune for best signal to noise.



Note the pagers above the 2 metre band in this spectrogram. The hump in the noise floor is the receiver super-regeneration side bands. The smaller peak in between is the output of the Fredbox transmitter, the leakage from the unshielded prototype on my desk operating into a 47 Ohm load. It is rather disturbing that the pager signals are *larger* than this local signal just a foot or two from the spectrum analyser antenna.



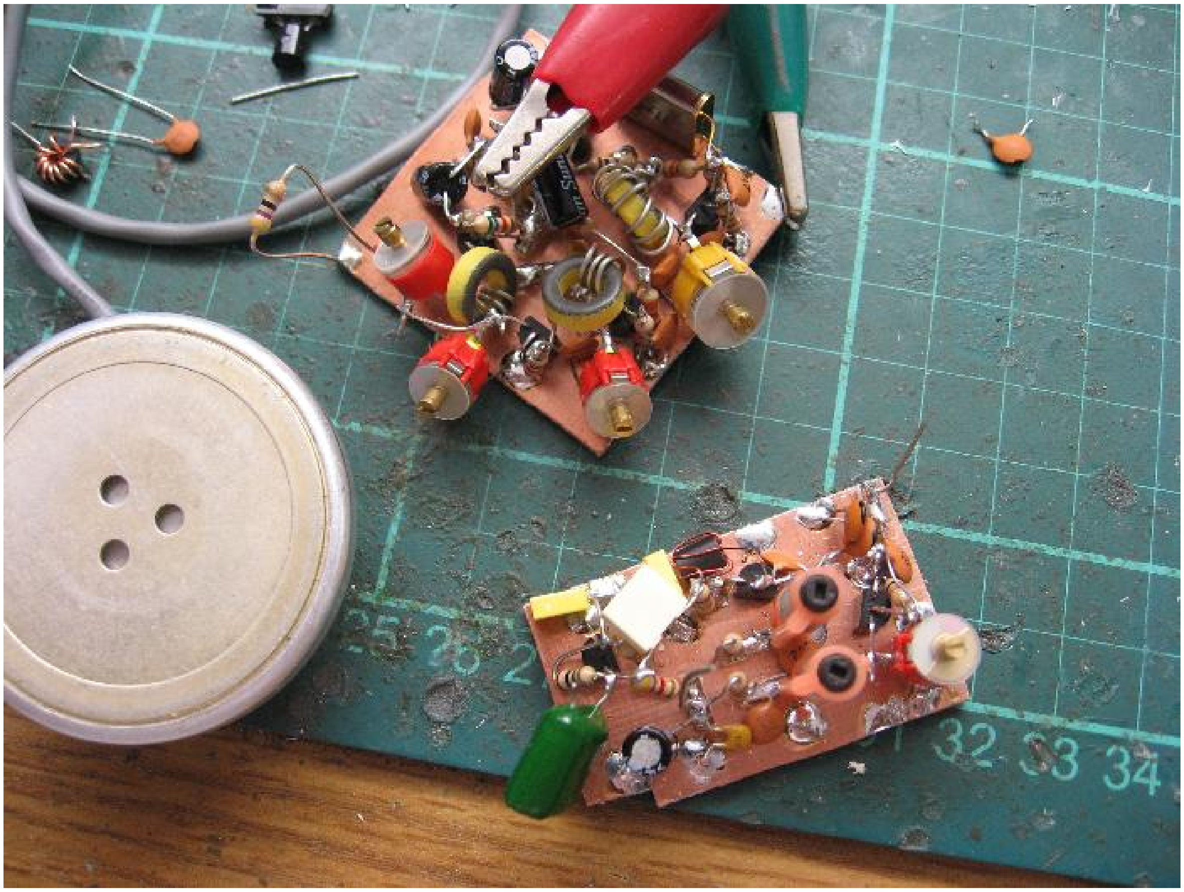
I used J310s for the receiver FETs, and a 2N3904 for the audio amp. Although the main design requirement for Roger appears to have been flea-power, I think a better AF amplifier that can drive modern low-impedance headphones would be preferable. Only Jaycar now carries crystal earphones with a nice soft silicone ear piece. The one I used comes from DSE and it is hard-plastic - not very nice on the ear. I really hate these kind of earphones anyway, I'll probably be rebuilding it for a low-Z output at some point, but it does work pretty well as-is.

BTW: While I was in the "Special Hell" of decoupling resonance I took the RX down to the FM broadcast band, and up to the VHF-hi TV band. It works wonderfully in both, which isn't a surprise. However, by adjusting the drain-source feedback (then a trimmer, now fixed) I

Hall's regen on the FM band. The topology is more forgiving however, allowing grounding of the tuning cap. I also built several different oscillator topologies in desperation before I identified the decoupling fault, in one I got a Colpitts-like oscillator working with emitter coupled feedback to a tapped capacitor across the tank. This is something I should have thought about a *long* time ago, I'll probably build yet another FM broadcast regen using this topology for the detector, it seemed quite easy to control just by manipulation of the base voltage.

Boxing It Up

I am still tossing up between a cast Aluminium box, a custom box folded out of Aluminium sheet, or an Altoids tin. The circuit is small enough to just fit inside an Altoids tin but it probably won't fit with a battery. I'll pick up a centre-off momentary-one-side switch over the next week and finish off the radio one way or the other.



Note the use of an old telephone receiver as the microphone. It is nearly as large as the entire TX board. I'll have to find my electret mics, I know I have a bag of them somewhere that I got from a Rockby sale.

I'm strongly considering rebuilding the radio, perhaps through-the-hole to minimise its size. Although my prototype isn't too large as-is, it would be nice to neaten it up. Maybe I'll build it with fixed caps and variable inductors to save space too, although shielded cans are about the same size. It *might* be possible to tune the multiplier stages with stretched coils and fixed caps, this would make it much more compact and save money too if it ends up being kitted...

More TX Power

I am considering running the unit on 12 Volts to get a bit more RF out, and perhaps building in a small amplifier to get it up to 1 Watt region. This would probably involve a rebuild of the TX side to use a 2N4427 or similar final device, and a more robust series modulator transistor. This won't be efficient, but is probably easier to get going than a linear amp which would need careful drive adjustment.

I'll probably conduct some experiments around using a 2N7000 or VN10KM as the output device. The math suggests they may operate on 2 metres. I've already got them working on 6 metres in a brief experiment last month (must document that).

Comments

Working with VHF is fun! I find it a great learning experience, especially when you get problems like the resonant decoupling cap. That kind of thing really pushes your understanding of the physics and teaches you a lot.

I know a lot of HAMs won't touch anything above the bandwidth of their oscilloscopes. I can understand the frustration when something doesn't work, especially when you can't see why, but it really isn't that much worse at VHF. With just a diode probe you can achieve a lot. It does help enormously if you have VHF test equipment, for example I likely would have never noticed the HF modulation problem had I not had a spectrum analyser (although the HF was visible on the collector of the modulator drive amp, and most of us have a CRO that can see fine near 16 MHz).

A wavemeter can be helpful, if a bit retro, especially for making sure your multipliers are tuned up right and for looking for spurs. You can build one quite easily, it only needs to be a resonator with a detector and a LED or meter as a read-out. I'm a big fan of the biased 1N5711 through the decoupled bottom of the tank coil topology. For super-sensitivity you can use a MPSA18 as a DC amplifier. With a signal generator or dipper and a counter or scanner/receiver you can easily calibrate it. It can be used like a poor-man's spectrum

My only advice when you get stuck is to trust the physics, do the math and follow your instinct when nothing is making sense. Rebuild parts of the circuit and test them independently. Measure what is actually happening and try to figure out what kind of misbehaviour in the circuit would cause the observed of behaviour. That will often solve an otherwise intractable problem.

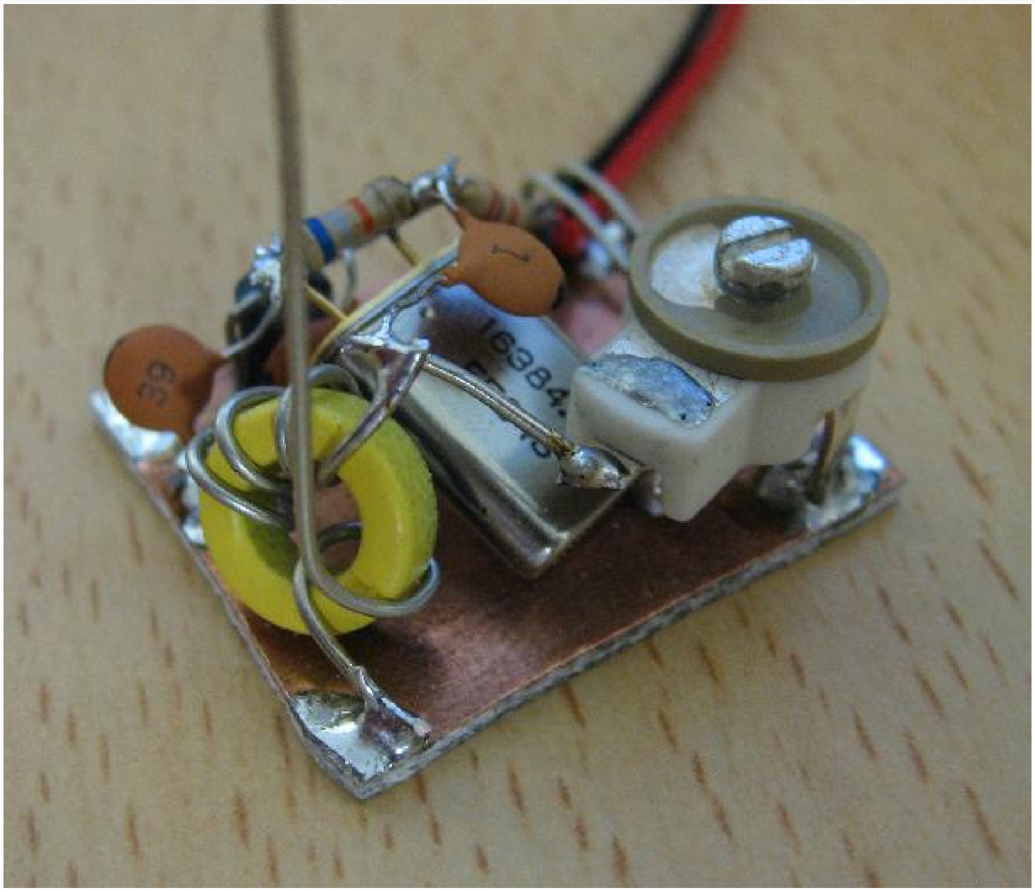
Update 2007-06-05

I took the Fredbox boards to the local Homebrew Group meeting. I had both halves hooked up and talking across the room. Peter VK2TPM had brought along a digital audio recorder and did an interview with many of us in attendance. You can hear what I said about The Fredbox on Soldersmoke 62, and even a brief snippet of audio going through The Fredbox.

Also on the recording are Peter VK2EMU talking about the 80 meter challenge, John VK2ASU talking about his transmitter modules for the challenge (and an interesting diversion into IRF510 gate-modulation with some input from Brian VK2TOX - something I was thinking about back here, apparently Drew Diamond VK3XU has already produced a design doing just this). Mike VK2BMR also talks about his great VSWR/power meter project. His unit was absolutely beautiful, I was very much taken by the excellent job he did of cutting the PCB stock that made up the external directional coupler box, essentially flawless, perfectly square workmanship.

Update 2007-06-09

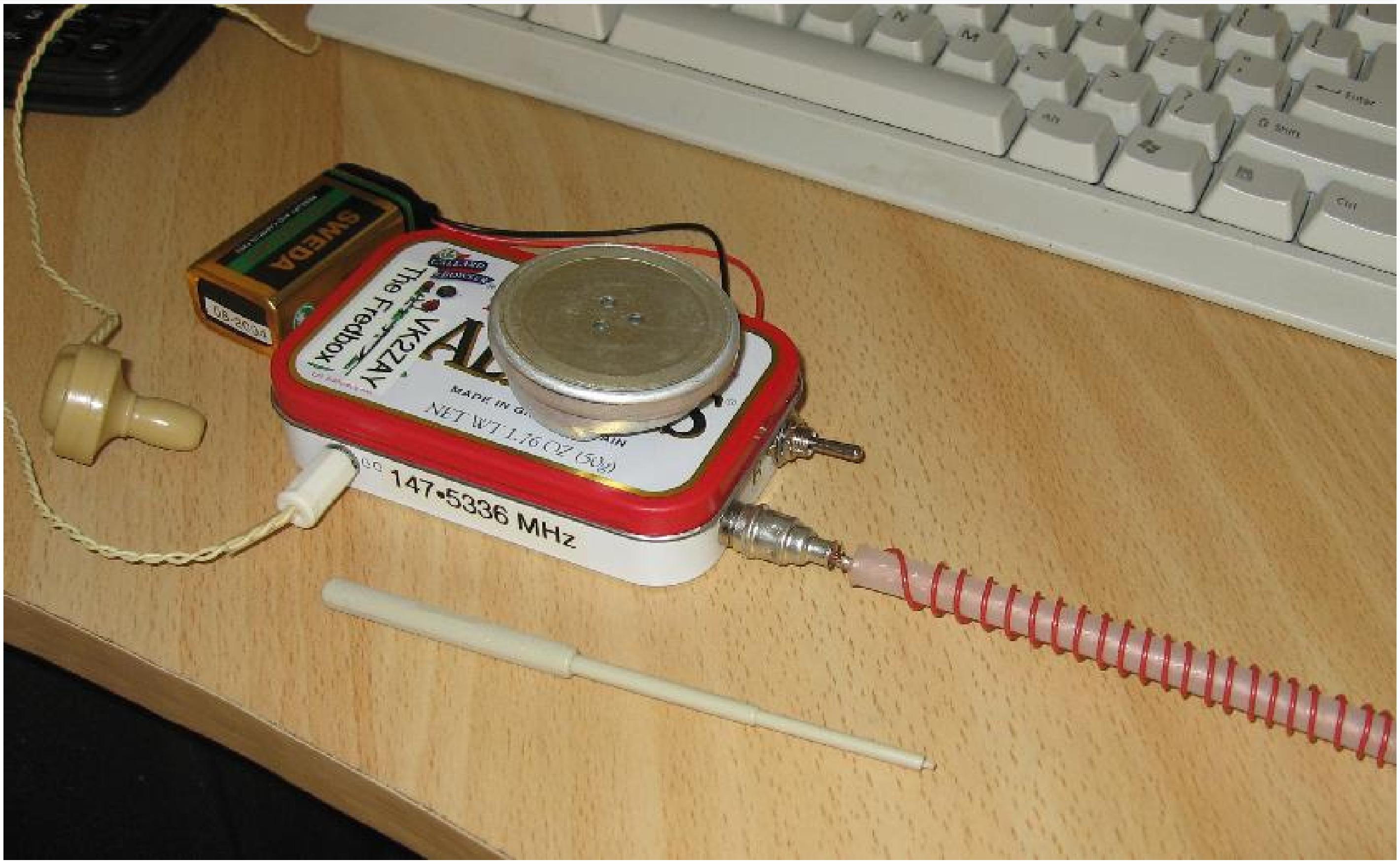
I've built a weak-signal source for aligning the receiver. One of the biggest weaknesses of the Fredbox receiver is that it drifts in frequency quite significantly with Vcc variations. Powered by a 9 Volt battery near the end of its life, it may drift enough to make the receiver completely off-frequency despite its poor selectivity. If I build this circuit again I'll probably put in a stabilized supply for the detector stage to avoid this problem.



The signal source is a Pierce oscillator driving a tuned circuit which selects the VHF harmonic of interest. Because of the oscillator topology the crystal isn't pulled down as much as in the Fredbox circuit. The difference is fairly minor for my purposes, the poor selectivity of the receiver makes the difference in frequency of no real consequence. There is no active (or passive) multiplier, so the tuned circuit is merely extracting the harmonic energy from the oscillator. The harmonic energy available is very small, which is perfect for the application, giving an almost undetectable signal 1 metre away.

Update 2007-06-10

I've boxed up the Fredbox. As discussed earlier I went with the Altoids tin, despite this not allowing the battery to also fit inside the enclosure. I tossed up soldering an additional tin to the back to hold the batteries, but for now I've gone with the 9-volt battery snap just hanging out. It will work well with 6xAA battery holders which can just be held to the box with a rubber band.



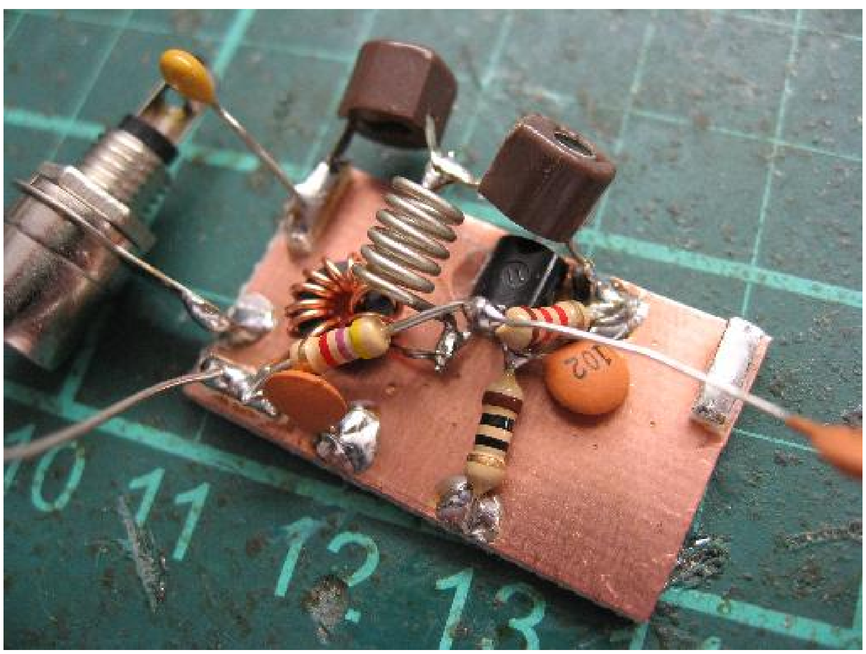
For the RF connector I chose an RCA. I can hear all the VHF engineers cringing, but for the purposes of this prototype it works just fine. The Antenna is a half-wave of wire helical which is quarter-wave resonant (with some pruning). The former is a piece of centre conductor and insulator from RG-213 coax. The centre conductor was left in place and is soldered into the RCA plug centre conductor, adding some capacitive loading and shortening the length of wire needed for resonance. I have no idea if this is good or bad, but it works.

I didn't find my stash of electret microphones, so I ended up just soldering the telephone receiver into the top of the Altoids tin. Ugly as hell, but also kinda unique. It looks somewhat like those Vietnam-war era VHF-low walkie-talkies.

I couldn't find a momentary-one-side toggle switch, so a centre-off on-both-sides switch was used instead. A special dummy load/diode peak-voltage probe was assembled for the final alignment. The carrier power ended up being near 25 mW on 12 Volts, on 9 Volts 10 mW just like Roger says in the article.

Update 2007-06-11

The 2N7000 on 2 metres experiment was a failure, it simply doesn't produce useful power beyond 90 MHz or so. However, it is very usable below 70 MHz. My input network was far from optimal, so perhaps with some more work it would be possible to get it working higher up, and I haven't tried an VN10KM in the same circuit.



I've also been fiddling around with grounded-base class-C multipliers. (Not just decoupled, biased base, the base actually soldered directly to the ground plane.) At first this seems a little weird, but if you pull the emitter low with a link-coupling to the previous stage collector current will flow. The advantage is excellent reverse isolation, which might help with stability with less than ideal layouts and devices. Such a topology was apparently quite common years ago with the 2N918.

1 comment.

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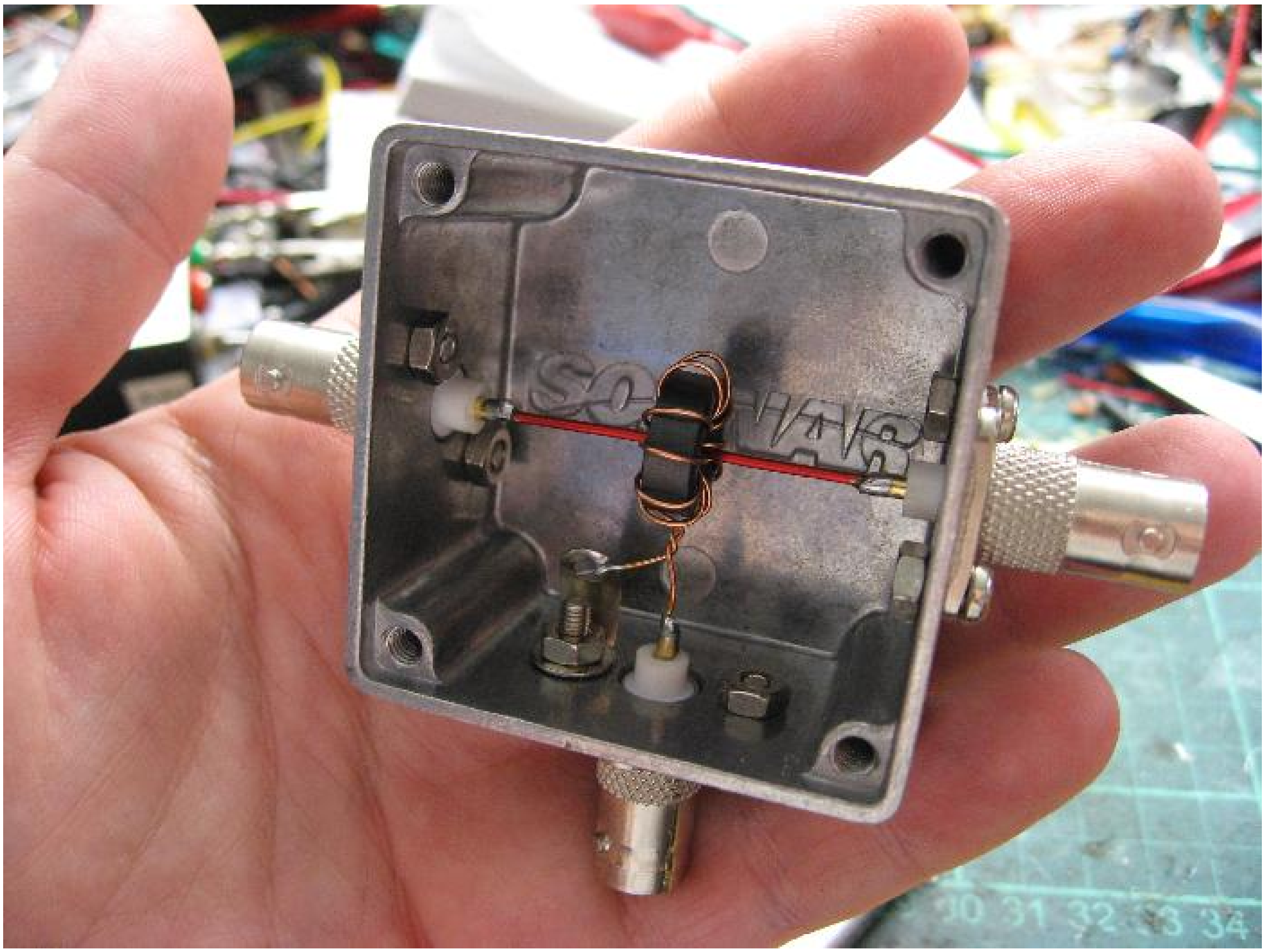
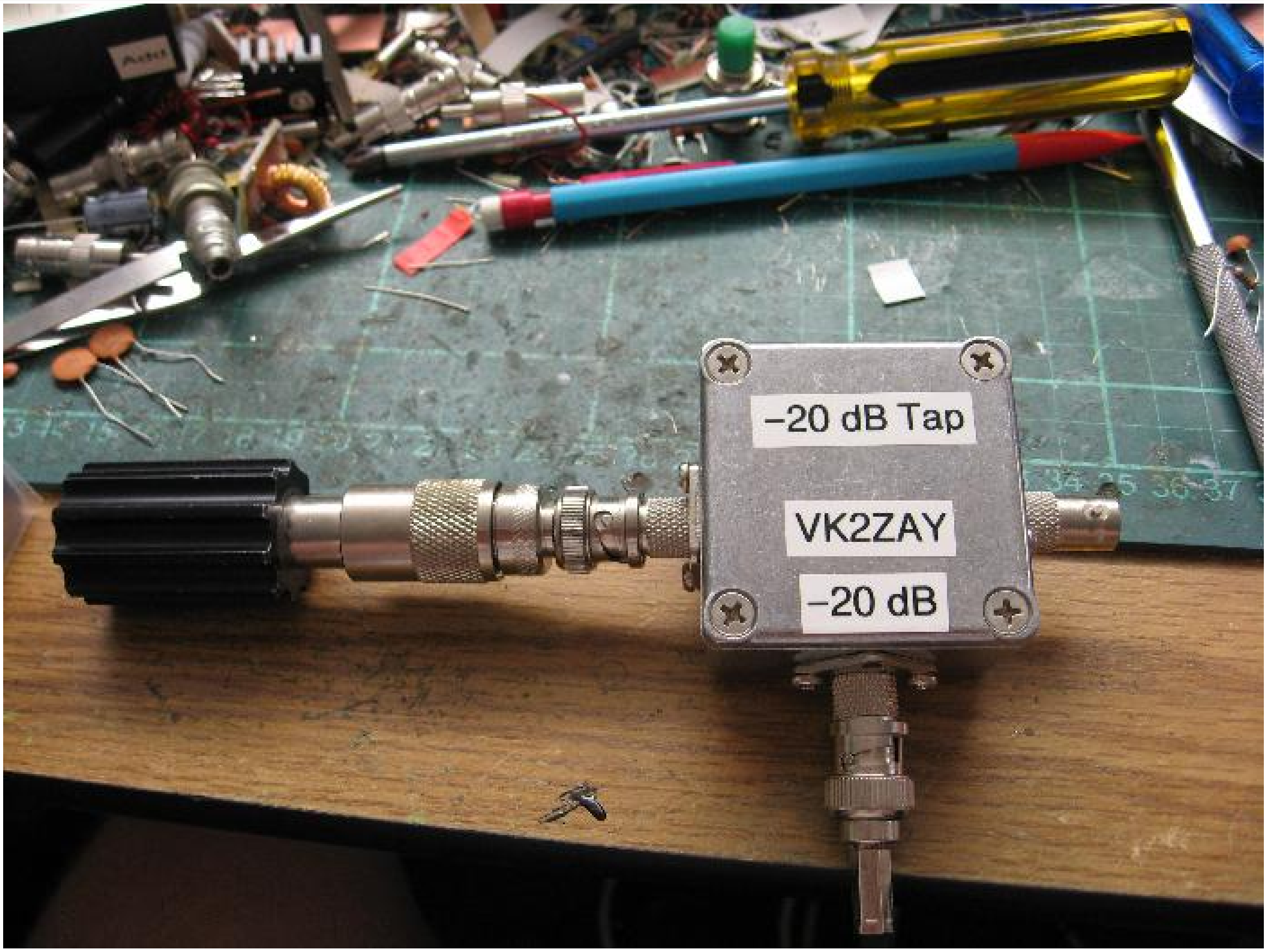
-20 dB Tap Attenuator

2008-08-23

Another device I've been meaning to build for a long time. The QRSS work has caused more interest in attenuators and transmission line monitoring, my current bodgy attenuator was tested with my most recent instrumentation and found quite lacking - more work on that instrument soon... Pi or Tee pads have precision issues, especially if you only stock E12 resistor values, so this tap is based on a transformer, the familiar 10:1 turns ratio -20 dB tap. It can offer quite good accuracy if carefully constructed and terminated correctly on all ports.



I tried various core materials and sizes. The FT50-61 was looking quite promising, especially at higher HF where its insertion loss is lower than type 43 material, but its performance didn't extend as well into lower frequencies so I settled on using an FT50-43 core. Physical construction in a diecast box limits the high-frequency response, and the inductance limits the low-frequency response. 10 turns on an FT50-43 is about 66 uH, using a 3 times the load resistance (50 Ohms) reactance (j150 Ohms) gives a lowest usable frequency of about 360 kHz. Experimentally roll-off starts to become annoying at about 400 kHz. On the high end the response is more difficult to predict and measure with my available equipment, I've only confirmed its response flat to 20 MHz, but a spot-test at 144 MHz using a 1 W HT as a signal source gave -20 dB to within my measurement accuracy at the tap port. Performance which I found quite surprising. I'm calling it 500 kHz to 20 MHz and have labelled it as such.



Precision wise my fairly limited measurement accuracy says better than +/- 0.3 dB 500 kHz to 20 MHz as long as both output ports are terminated properly. I can't stress that enough, if the "thru" or "tap" ports aren't terminated in 50 Ohms (or whatever you're measuring in/from - the BNCs are 50 Ohms units) the attenuation will be wrong. To be completely correct, the 10:1 turns ratio transformer reflects a resistance 100 times smaller than the tap termination in line with the thru termination. So 0.5 Ohms from a 50 ohm tap termination is added to a 50 Ohm thru termination (or a 1 % error). This means the total load impedance is slightly wrong, and the return loss seen looking into the input is measured slightly worse than just into a dummy load, but the effect is quite small and much better than my best -20 dB Pi attenuator constructed using E12 5% value resistors.

Notes

Construction using a binocular core might be superior.

You may be able to extend the HF performance by using a length of coax through the core, earthed at only one end to the box. This will minimise the impedance step created by transitioning from the coax/connectors into the lumen of the box where the wire to box geometry gives nothing like 50 Ohms of impedance. HF response will still be limited by mismatch effects (and eventually modeing inside the box), but type 43 ferrite is only good to low UHF anyway.

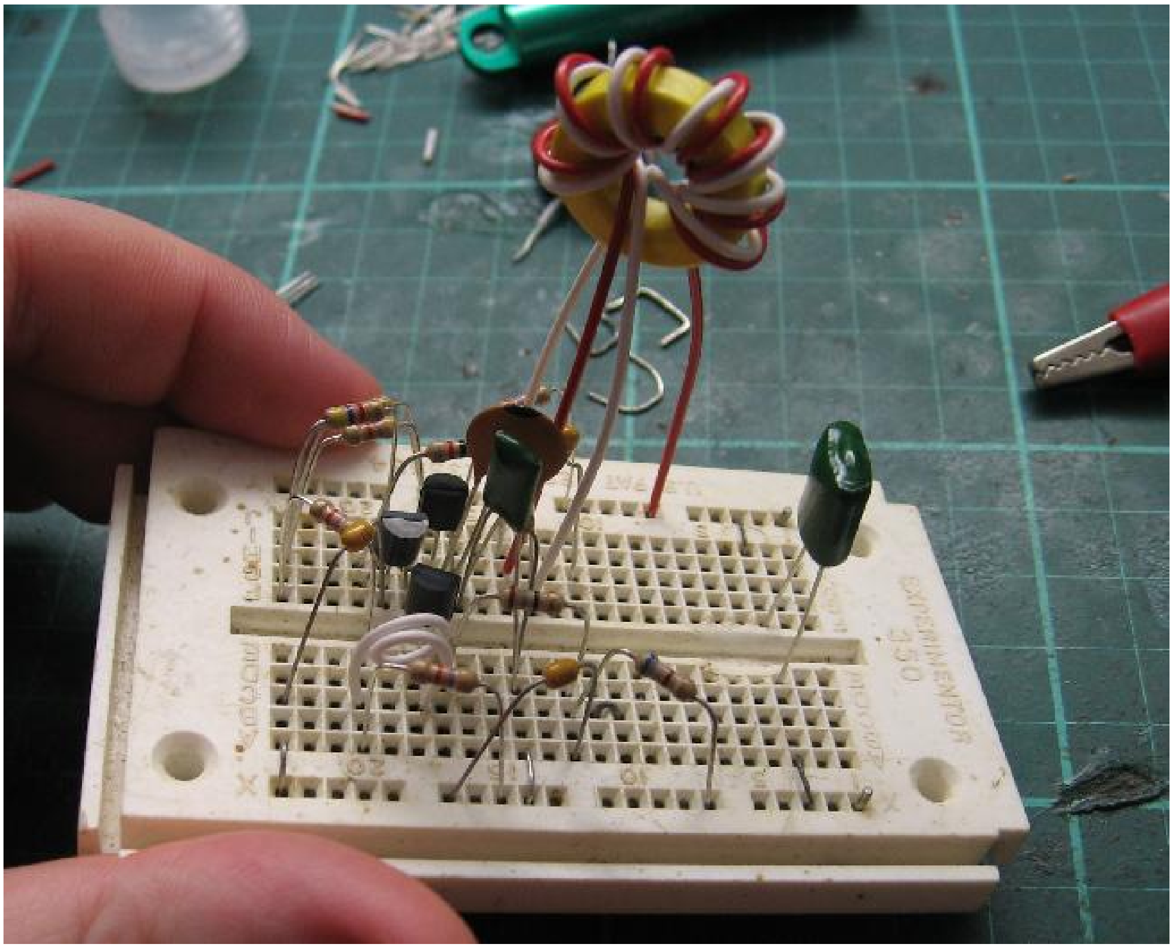
I've ordered some PCB-mount BNCs that are constructed like your typical SMA connector with four solder pins around the centre one. Using these and FT23-43 cores it should be possible to construct a similar but lower power device usable to low UHF. There is no reason why you couldn't "ring-bark" some RG-58 or RG-174 coax and construct the transformer directly over the coax, then re-complete the braid circuit with metal shim-stock or tape over the transformer. I once constructed a VHF directional coupler by passing insulated wire under the braid of a piece of RG-213, it worked quite well.

Leave a comment on this article.

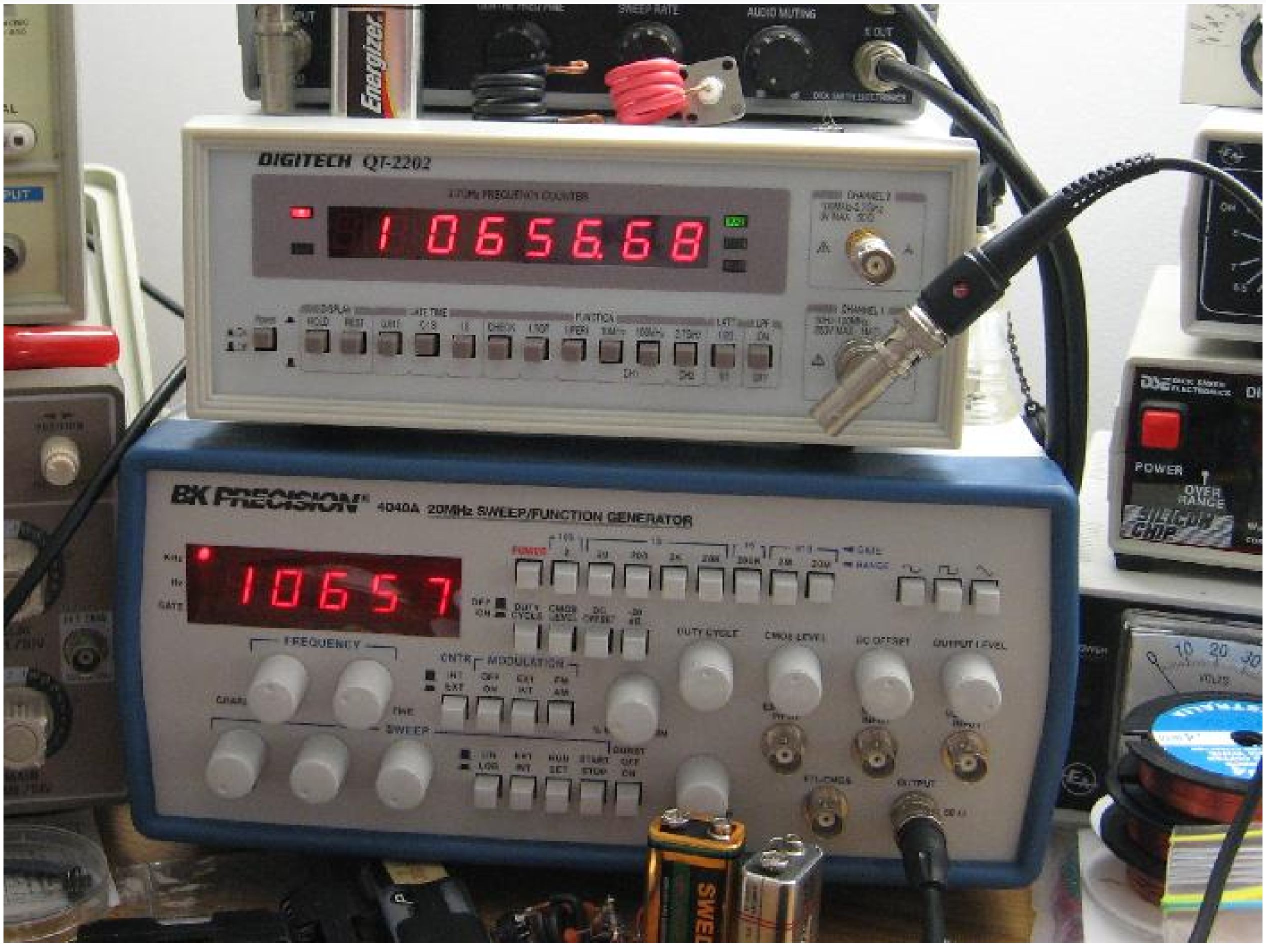
30 Metre Autodyne Receiver

2008-01-27

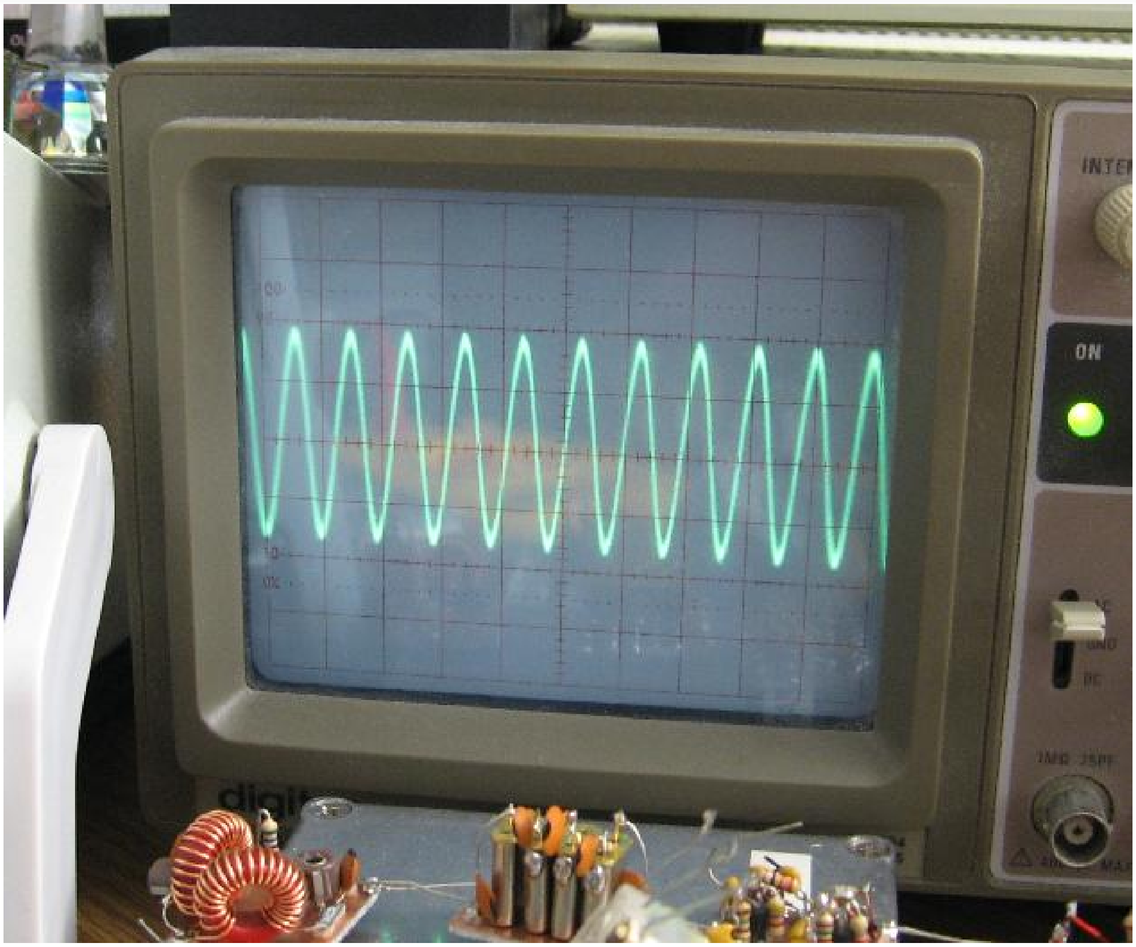
As mentioned in the Australia Day article, building this receiver was the result of QRP-L discussions of WWV receivers. The design comes from Nick Kennedy's page, and itself seems to be the result of QRP-Tech discussions. I only discovered QRP-Tech last week, and just subscribed, looks better than QRP-L which has a somewhat worse signal to noise ratio if you interests are more technical.



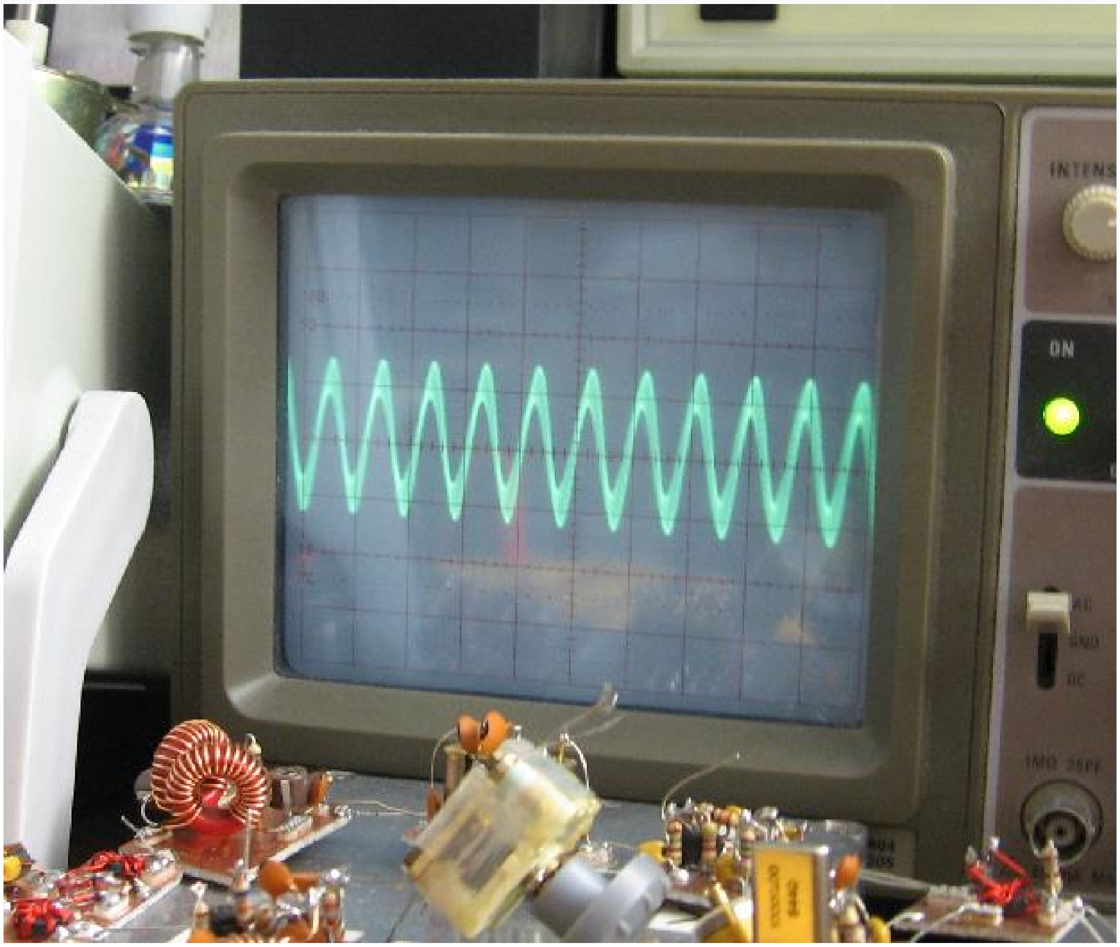
The receiver worked fairly well breadboarded, but did suffer from tunable-hum. This isn't surprising, as unshielded it is essentially a direct conversion receiver and the LO was illuminating all kinds of mains powered devices in close proximity. In particular my soldering iron which seems very efficient and hum modulating the near-field of coherent detectors. The breadboarded prototype wasn't (easily) tunable, but would lock my noisy BK (im)Precision generator/sweeper and hold it indefinitely with sufficient signal.



What does this look like in the time domain? When locked the LO perfectly phase-tracks the RF signal. When unlocked you see hetrodyne from the frequency difference of the LO and RF. Triggered from the RF signal you see something like this:

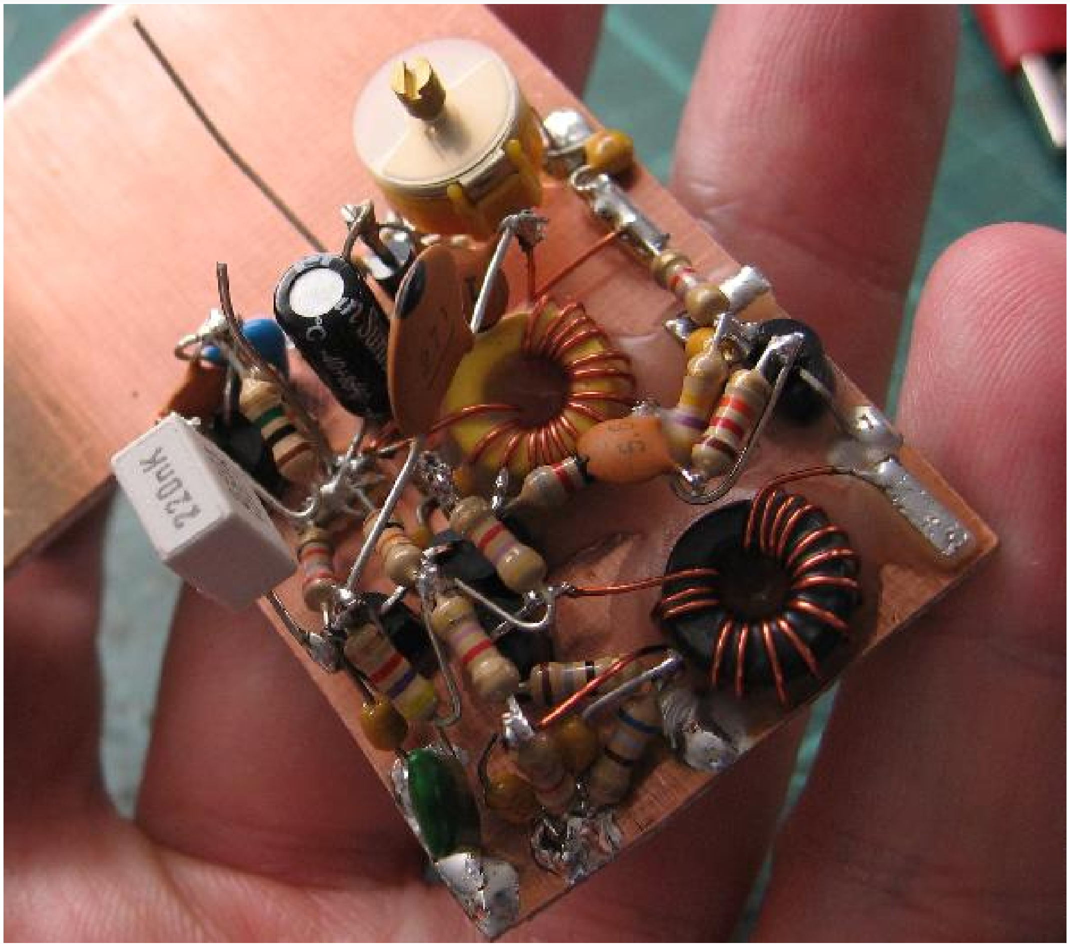


And unlocked, this:



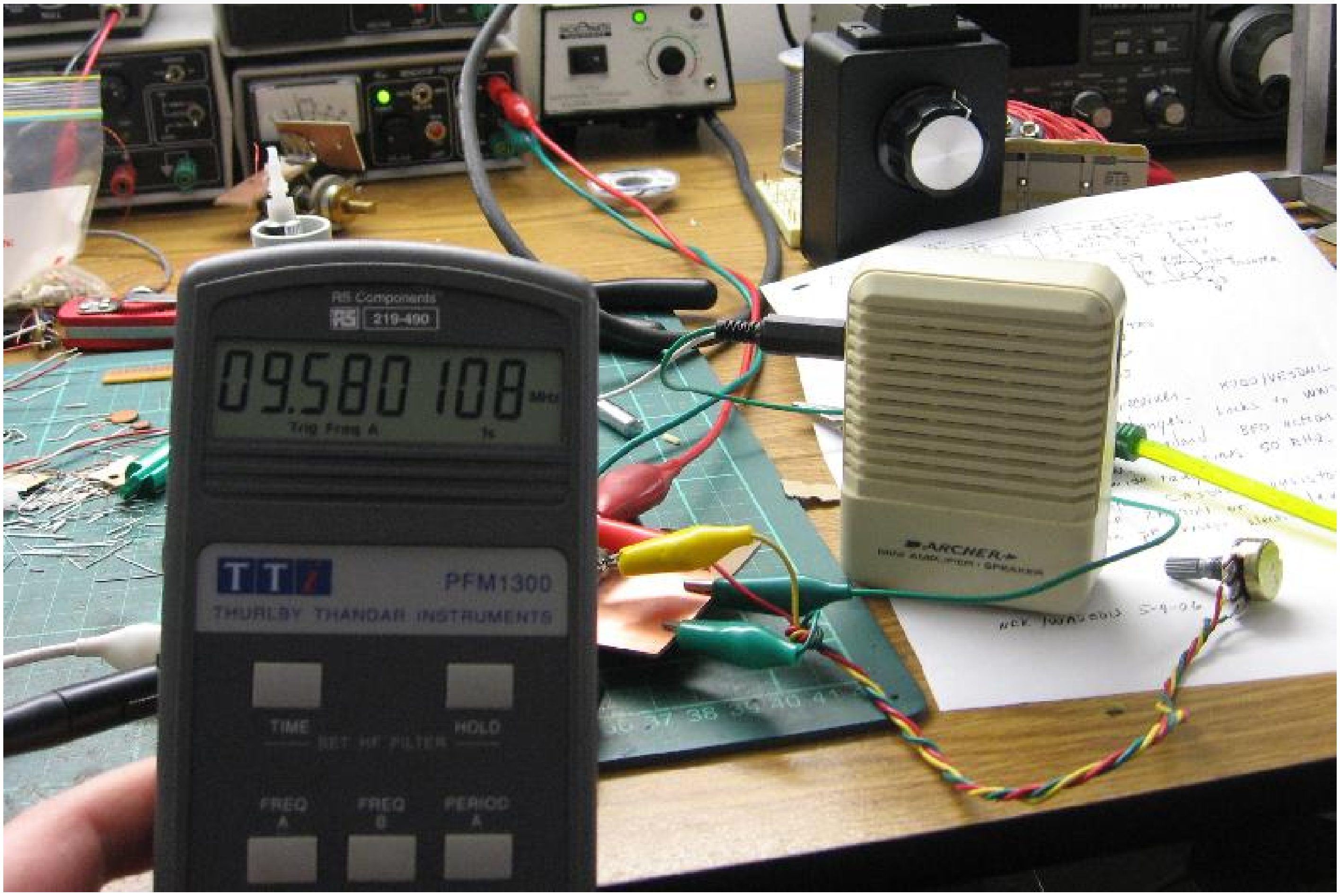
I had a much better dual signal trace with the LO and RF triggered from the RF in several configurations, but I didn't take pictures, sorry.

Akshay Parelkar VA7AAX shot me an email about the bread boarded version shortly after I posted it, and inspired me to build it properly.

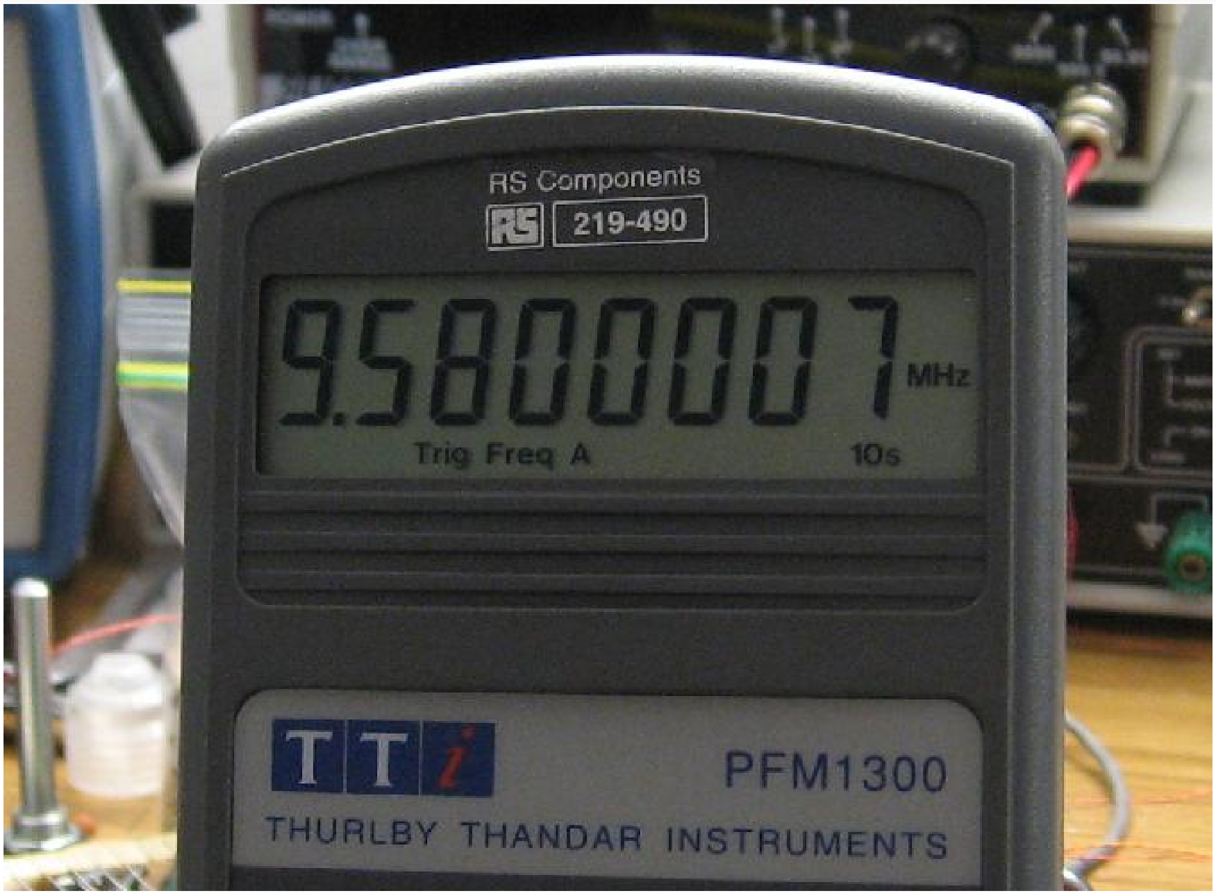


With the toroids waxed to the board and a trimmer to bandset the receiver more practical tests could be made. The varicap (1N4007 rectifier) gives a good range for fine tuning and it is quite easy to lock moderately strong shortwave signals with just an alligator clip lead for the antenna!

WWVH is far too weak here to lock with such a primitive antenna, or even really hear above the garbage coming from my computers. However the 31 metre broadcast band gave me plenty of strong signals to experiment with. Radio Australia gave three closely spaced, rock solid signals. I could also hear a few others, but I didn't catch their call signs. Quite surprisingly I could briefly lock them too as their signals came up.



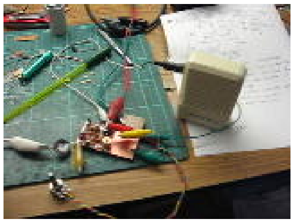
Apparently my counter's frequency reference disagrees with whatever Radio Australia is using. I assumed they have a precision clock. All three Radio Australia signals seemed to disagree by the same amount, as did the others I could briefly lock, so I took the leap and tweaked the calibration of my counter to reduce the error.



The lash-up held this to within 200 mHz for over an hour. Pretty good considering my counter has only a fairly cheap reference. Now and then the signal would fade and the receiver would break lock. The hetrodyne was immediately obvious and a tweak of the tuning pot would relock it, or the signal strength coming back up would also drag the LO back into phase lock.

Videos

There was something about the Australian Open on Radio Australia at the time I was experimenting with the circuit. Here is a video of a rocking the receiver across lock with the strongest copy. I also stick my finger near the tuned circuit which pulls it off lock temporarily. You'll note how it captures the carrier of the station, a normal direct conversion receiver would have all kind of beating and phasing effects as you approached zero-beat.



Tuning the Receiver across 9.58 MHz
(3.102 Mbytes)

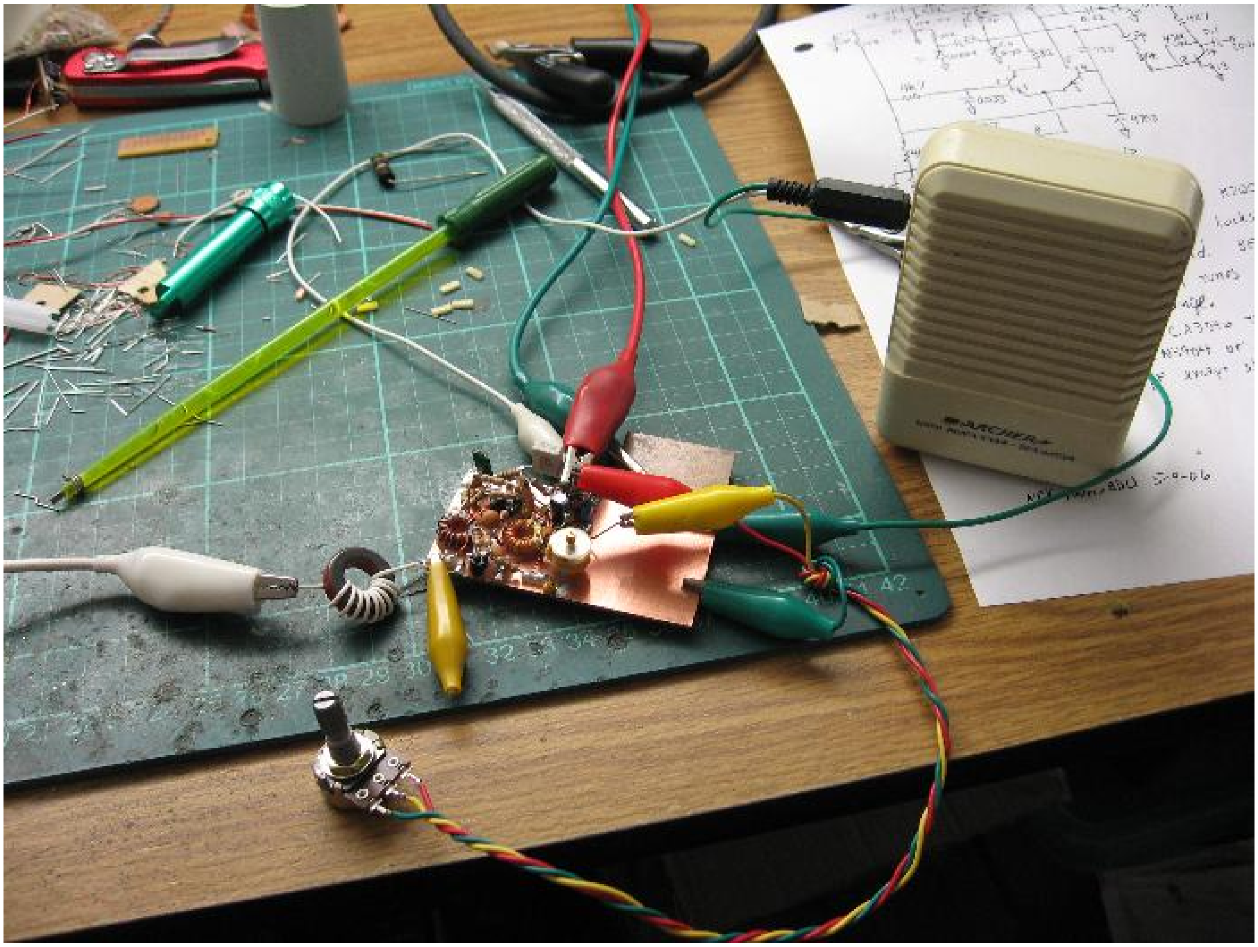
Radio Australia was transmitting three signals separated by only 10 kHz, here we have a video of tuning across all three. It displays the heterodyne heard when the receiver is unlocked, and the locking effect once you are close enough to the carrier. Observe the frequency counter settling into each of the frequencies once lock is achieved.

Tuning Across Radio Australia's Three Signals
(4.006 Mbytes)

Problems

One minor problem with the receiver is VHF interference. The 270 pF capacitor that feeds back the LO tank to the transistor base appears to be resonant in the FM broadcast band. At one particular setting of the bandset trimmer 2MIX FM 106.5 MHz can be heard! Shielding the unit inside a box would fix this (and any final traces of direct-conversion LO radiation hell). It seems to be largely direct pick-up by the circuit, although putting a lashed-up low-pass filter into the antenna line did reduce the problem a bit.

I mentioned to Akshay that I thought the receiver needed a real front-end. A 30 metre bandpass is advised. I can't imagine what would happen with a real antenna rather than just a foot-long clip lead!



Better layout might be advised, reducing the length of all the HF circuit paths and pushing any possible spur resonances above the transistor bandwidth. I tried beads on the transistor base, but it killed the oscillation as well. Experimentation with a small amount of additional Miller capacitance may tame any VHF oscillations.

The VHF interference does suggest a similar circuit topology might work quite well as an FM radio autodyne front-end. Even fairly modest modern transistors (I used 2N3904s) have huge bandwidth in the differential configuration. I'd imagine it would be possible to have one side a tuned LO resonator and the other an IF one, with the cascoded transistor in the tail as the input buffer.

Notes

This autodyne receiver implements a coherent AM demodulator, which has some advantages to conventional envelope detection. It lacks AGC, which is annoying for general shortwave reception, but otherwise it makes a pretty good general purpose receiver. It can receive AM, CW and SSB with one only adjustment (tuning), unlike a regenerative set. Strong CW signals can grab the LO though, and pull it, right into lock in some cases, eliminating the beat note! Also, strong adjacent signals will capture the LO pulling it into around, which can be extremely annoying. If there is sufficient noise margin just attenuating the signal will help.

I shunted the AF amplifier feedback resistor with a 1 nF capacitor to roll off the HF response. The audio was otherwise a bit sharp. You might like to add a pair of cascaded Sallen-Key filters to roll it off more sharply and improve the selectivity. I wouldn't recommend the receiver for CW, but you might also like to add a 700 Hz bandpass for that purpose if you intend to use it. Not too tight though, its a bit chirpy with strong adjacent signals.

I used the same turns ratio at the input transformer, but wound 3:12 instead. This isn't too critical really, and I am yet to measure the input impedance or attempt to predict it, I'd imagine it will be moderately high though.

Shield your counter interconnection, LO leakage here will cause the all too familiar direct conversion tunable hum problems. The buffering is generally sufficient, but I can hear the count windowing of one of my counters back through the AF output which suggests you might like to improve it. A common-base isolator or padding will probably help. I picked off the LO at the tap point on the tank rather than its hot end, this reduced the effect of the load compared to the original design.

Updates

2008-02-04: Autodyne Receiver Now In a Box
I add a front-end and a box to the 30 Metre Autodyne Receiver

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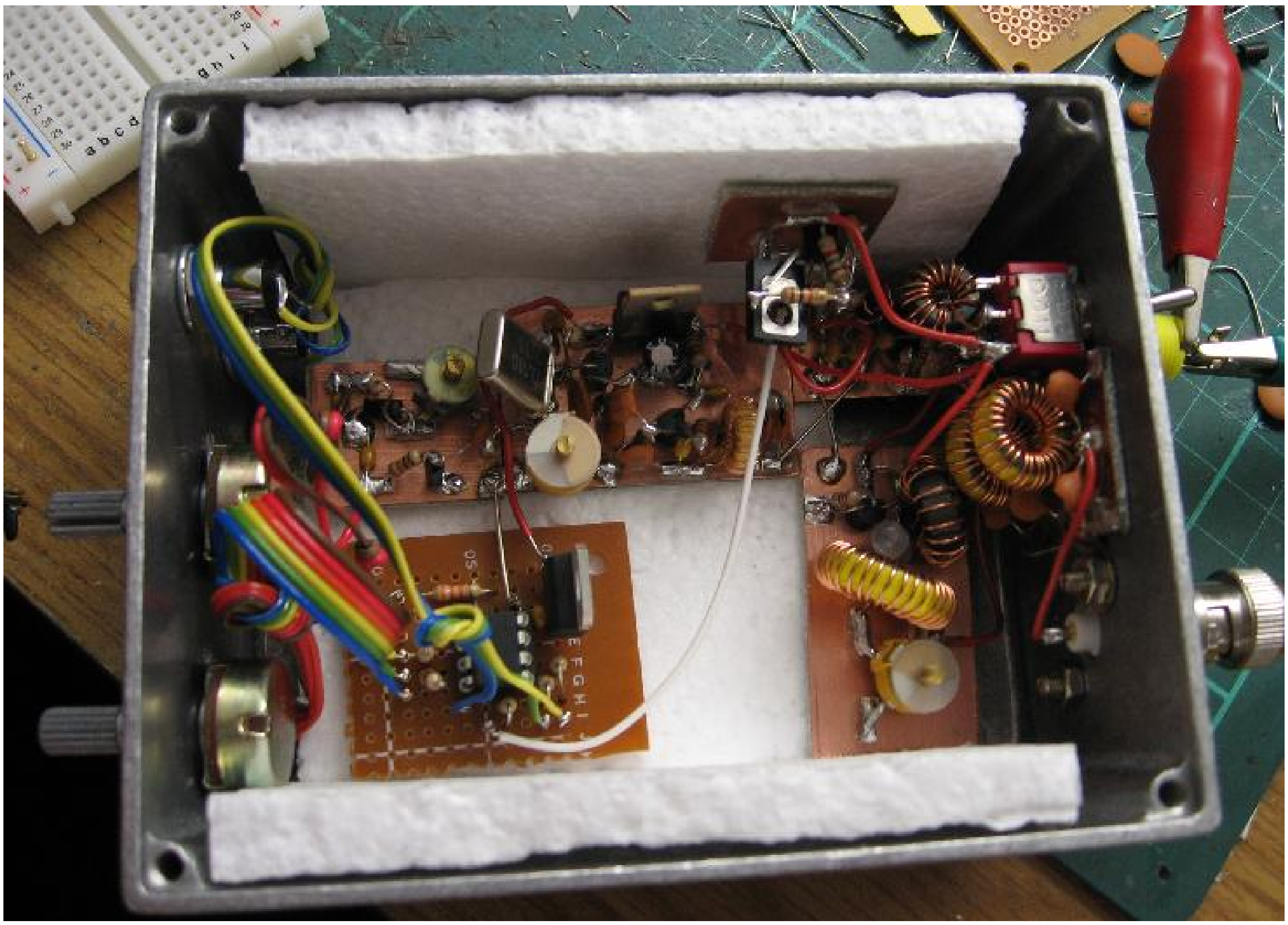
30 Metre QRSS Beacon Updates

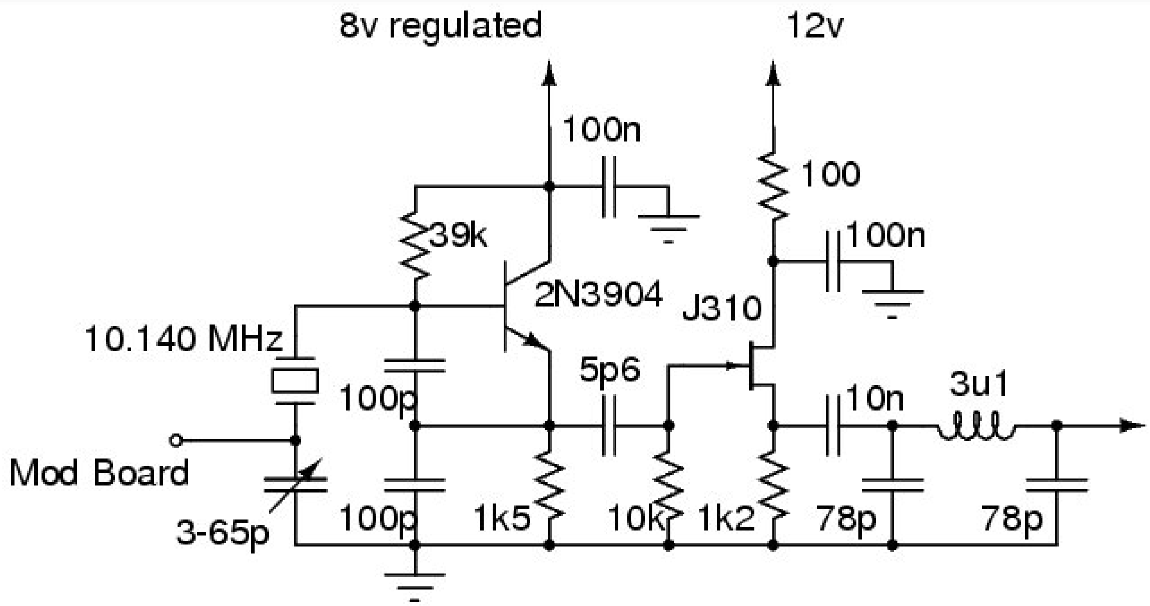
2008-08-16

The MEPT Beacon has gone through some steady changes over the past few days. Most importantly it is now in somewhat of a "finished" state, stable and boxed-up ready for real transmitting experiments. A fourth piece of foam surrounds the circuit for insulation once the top is closed, the open ends of this "oven" don't seem to hurt. Modules are (clockwise from the microcontroller board); The ATtiny13V based controller, the fine tuning and FSK modulator, the carrier oscillator and buffer, the amplitude modulator (on wall), the driver amplifier, the low pass filter (on wall), and finally the class-E power amplifier.



Carrier Oscillator

Essentially unchanged from the original circuit, except I have stripped out the diode switched modulation trimmer and replaced it with the frequency modulation and tuning board. Conventional Colpitts oscillator using a 2N3904 buffered by a J310 with a low-pass filter delivering 900 uW into 50 Ohms.

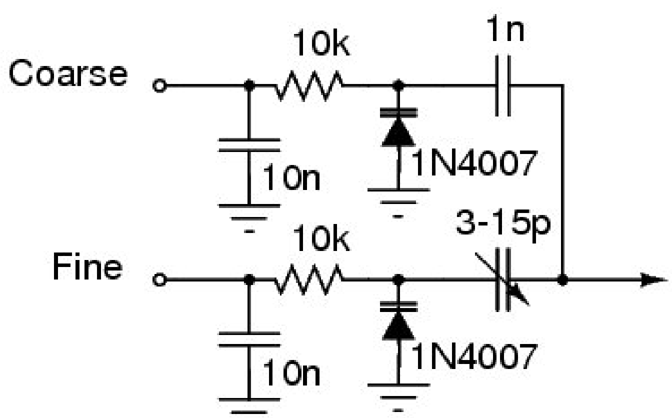


That 3.1 uH inductor in the filter is implemented by 32 turns on a T37-6 toroid. The 78 pF caps are two 39 pF in parallel.

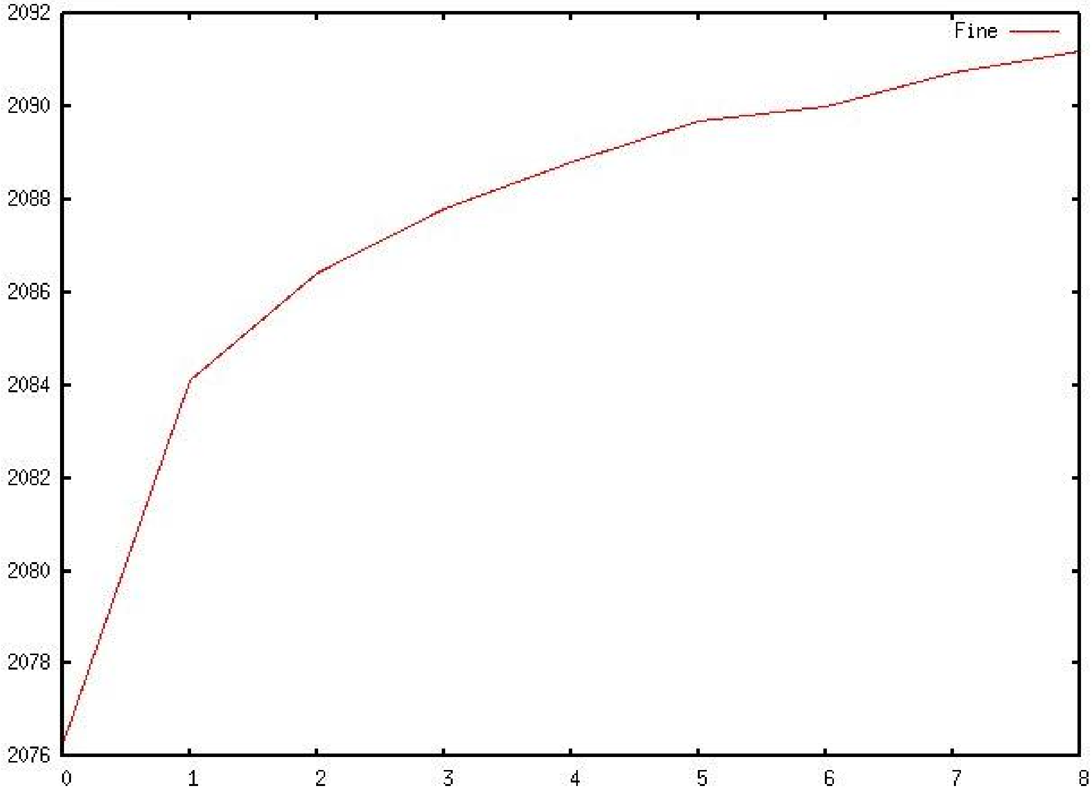
The reverse-isolation of this circuit is pretty good. It might be used as-is for a QRPp beacon or with the driver amplifier for 14 dBm output which is quite usable.

Frequency Modulator and Tuning

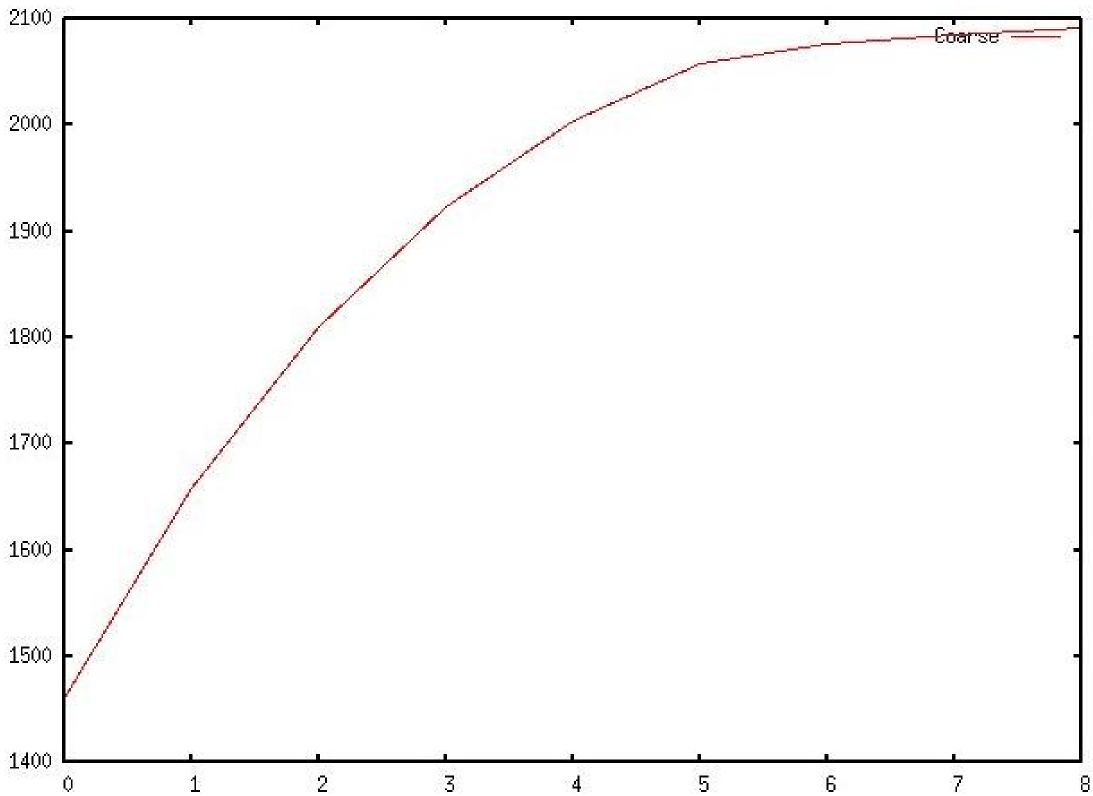
A pair of 1N4007s are used as varactor diodes. I picked 1N4007s not because they are particularly well suited, but simply that I had some on the bench. One of the varactors is directly coupled to the xtal circuit through 1 nF so most of its capacitance change is seen, the other is coupled through a small trimmer to adjust its maximum effect. This gives two independent channels, one for relatively coarse frequency tuning, the other for FSK modulation. Thanks to John for his suggestion around this part of the circuit.



The varactor modulators were characterised to design the bias network in the controller for best linearity and desired range of shift (etc).



Fine was measured with the coupling trimmer quite loose, and subsequently tightened on final assembly to give a good maximum modulation width.

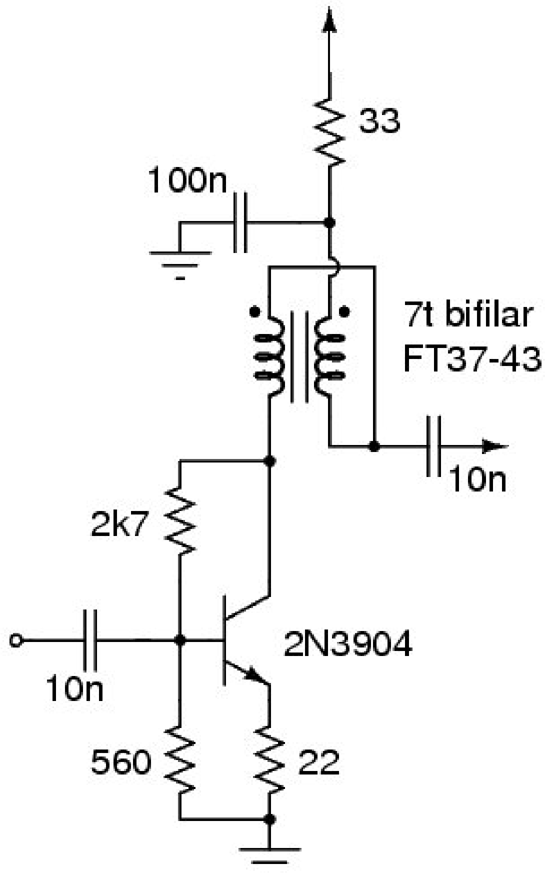


The data looks characteristically parabolic as expected. I suspect the oddness of the fine is measurement error. The y coordinates are in Hz relative to 10.138000 MHz (x is reverse voltage) so it doesn't take much error in measurement to make the fine trace look lumpy.

Driver Amplifier

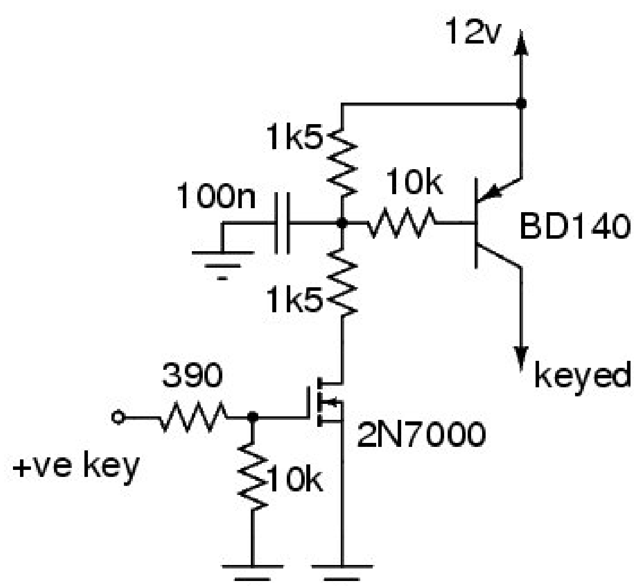
The driver amp is a simple 2N3904-based feedback amplifier delivering about 25 mW from the 800 uW output of the oscillator board. The amplifier input impedance is about 300 ohms when loaded with 50 at the output, this is a pretty serious mismatch

the circuit in practice measured about 15 dB transducer gain from using the oscillator as a signal source, probably because of the increased output of the oscillator with the lower loading offered by the input impedance (compared to a dummy load). DC input power is about 500 mW, so this stage is woefully inefficient, running at its limits, and should probably be redesigned. The supply line is keyed by the amplitude modulator to affect CW modulation.



Amplitude Modulator

The amplitude modulator is simply a BD140 PNP transistor with a 2N7000 switching its base voltage. A resistor network gives some envelope shaping to soften the keying. In theory PWM could be used for fine-grain power control from the microcontroller board, but I don't think I will attempt this.

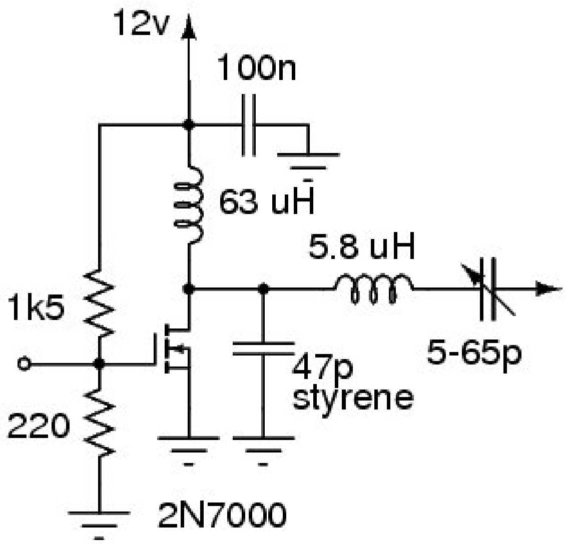


Power Amplifier

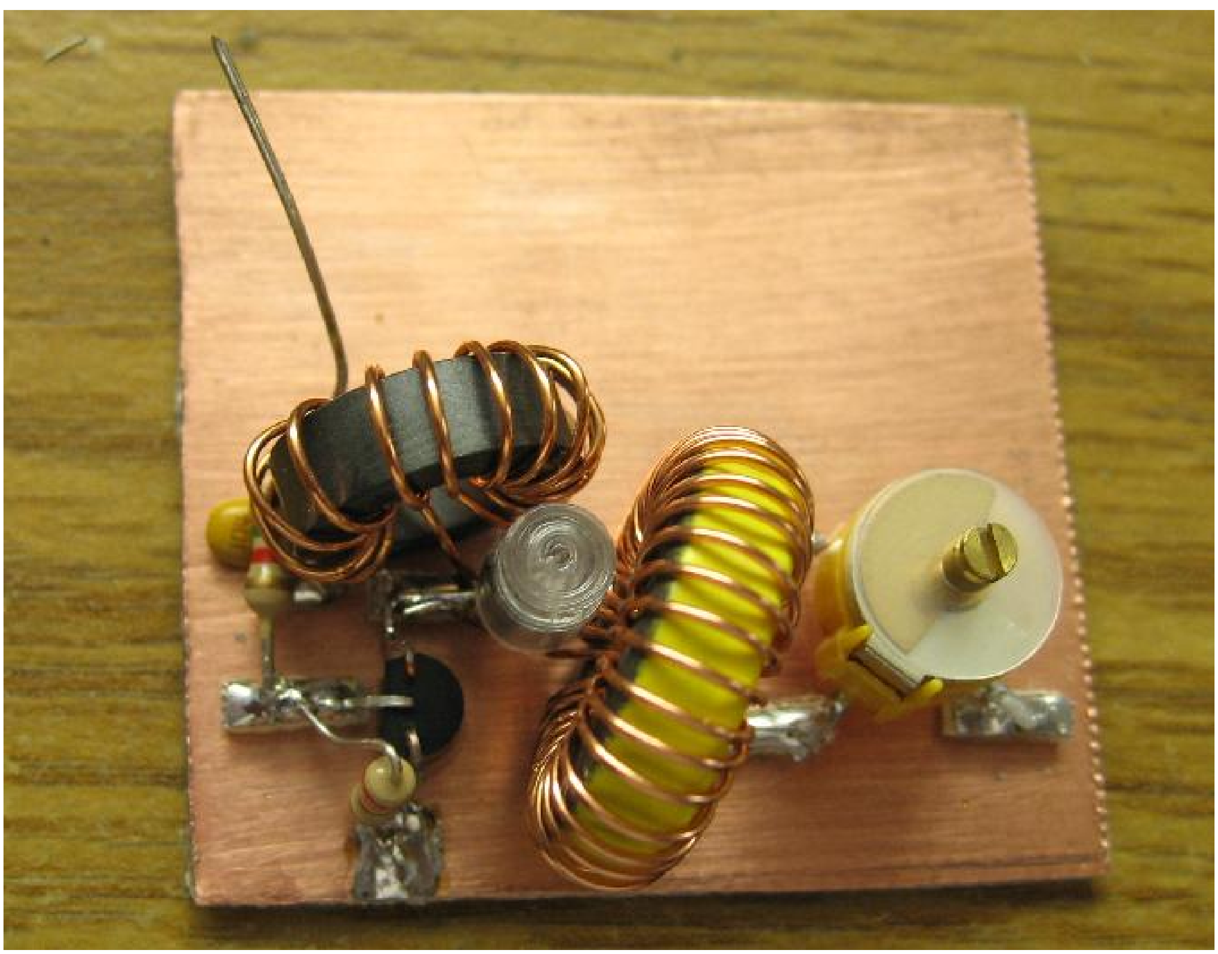
The power amplifier is a single 2N7000 running Class-E. From its 25 mW drive it can deliver about 2 Watts output (33 dBm) through the output filter into 50 Ohms from a 13.8 Volt supply. It barely gets warm although it is biased very slightly on by the

drive voltage. At the normal supply voltage (regulated 12.0 volts) it will deliver about 1.5 Watts - note also that optimal tuning changes noticeably with a change in supply voltage.

Impedance matching into the gate could be better but I suspect acheiving a good return loss would reduce the drive voltage amplitude and kill the output power, another active device would likely be required - in any case the impedance doesn't appear to upset the oscillator buffer LP filter even though the driver is partially "transparent" being a feedback amplifier. The mid-stage filter is largely redundant, but was useful for initial experiments, you might like to omit it.



I wrote a calculator to help design class-E amplifiers. The design was based around 1 Watt out from a 12 Volt supply and a loaded Q of 5. The result gives a load of about 75 Ohms, but empirical tests showed 50 Ohms was suitable loading giving a sightly worse efficiency and more voltage at the drain (without changing the shunt capacitor). The shunt capacitor value was decreased from the calculated value to match the output capacitance of the 2N7000 (about 18 pF), experimental measurements closely agreeing with theory. Even better efficiency is likely achievable, but the circuit works quite well as-is.

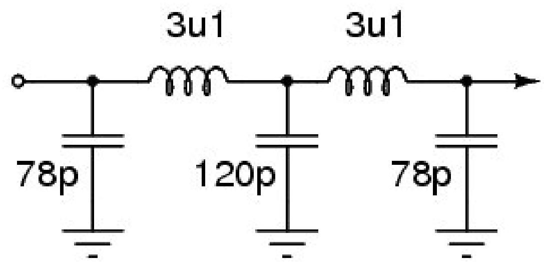


The drain choke is 12 turns on an FT50-43, its precise value is not critical, it just acts as a current source and could be (and perhaps should be) much smaller - the calculator does make a (very tiny - often ignorable) adjustment for its admittance. The

analysis was not carried out, T50 or perhaps even T37 might be OK? The trimmer is probably not the best for higher Q circuits, but at 5 it seems to work OK and doesn't get hot.

Low-Pass Filter

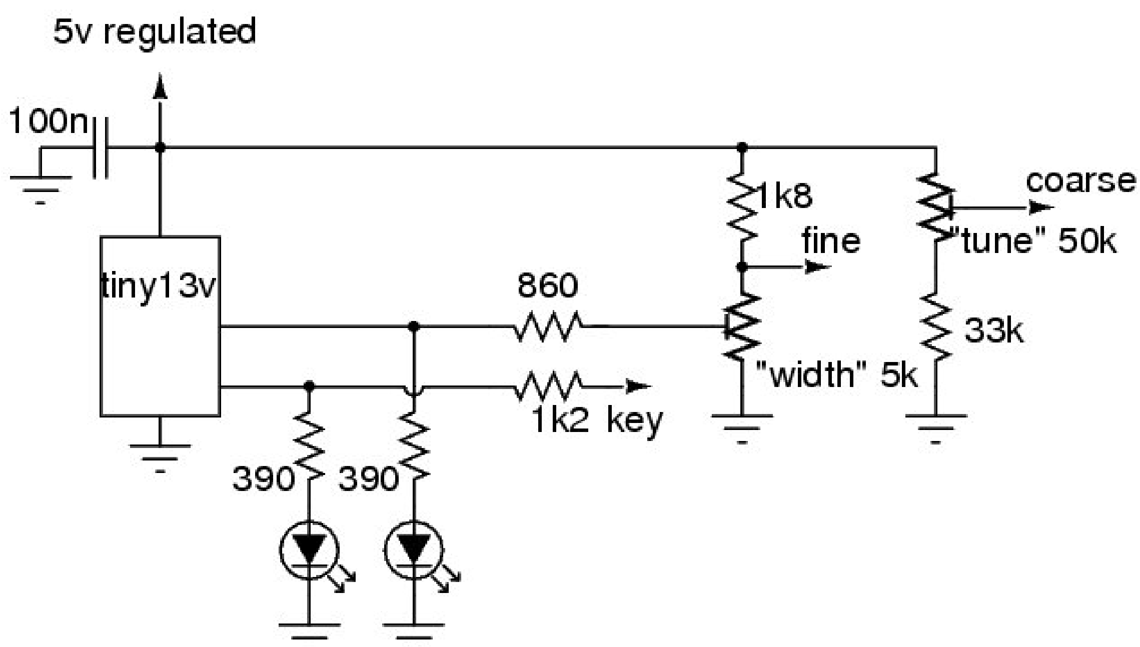
The filter is a Chebyshev with its final peak at the frequency of operation. It has pretty good measured characteristics, the centre capacitor was tweaked to tune out the effect of using E12 preferred values. Normal ceramic capacitors were used with no measurable ill effects.



The 3.1 uH inductors are 28 turns on T50-6 toroids.

The Controller

An ATtiny13V is the brains of the MEPT beacon. The microcontroller code hasn't changed since the original build. The board also contains the resistor network for deriving the modulator and tuning signals from the "width" and "centre" pots, in addition to the green indicating LEDs which show the CW and FSK keying state.



There are some elements omitted from these diagrams, for example the 5 and 8 volt three-terminal regulators, some filter capacitors, decoupling, supply filtering at entrance to the box, etc. All are extremely non-critical and conventional so I haven't detailed them here. Please post a comment if you want anything clarified.

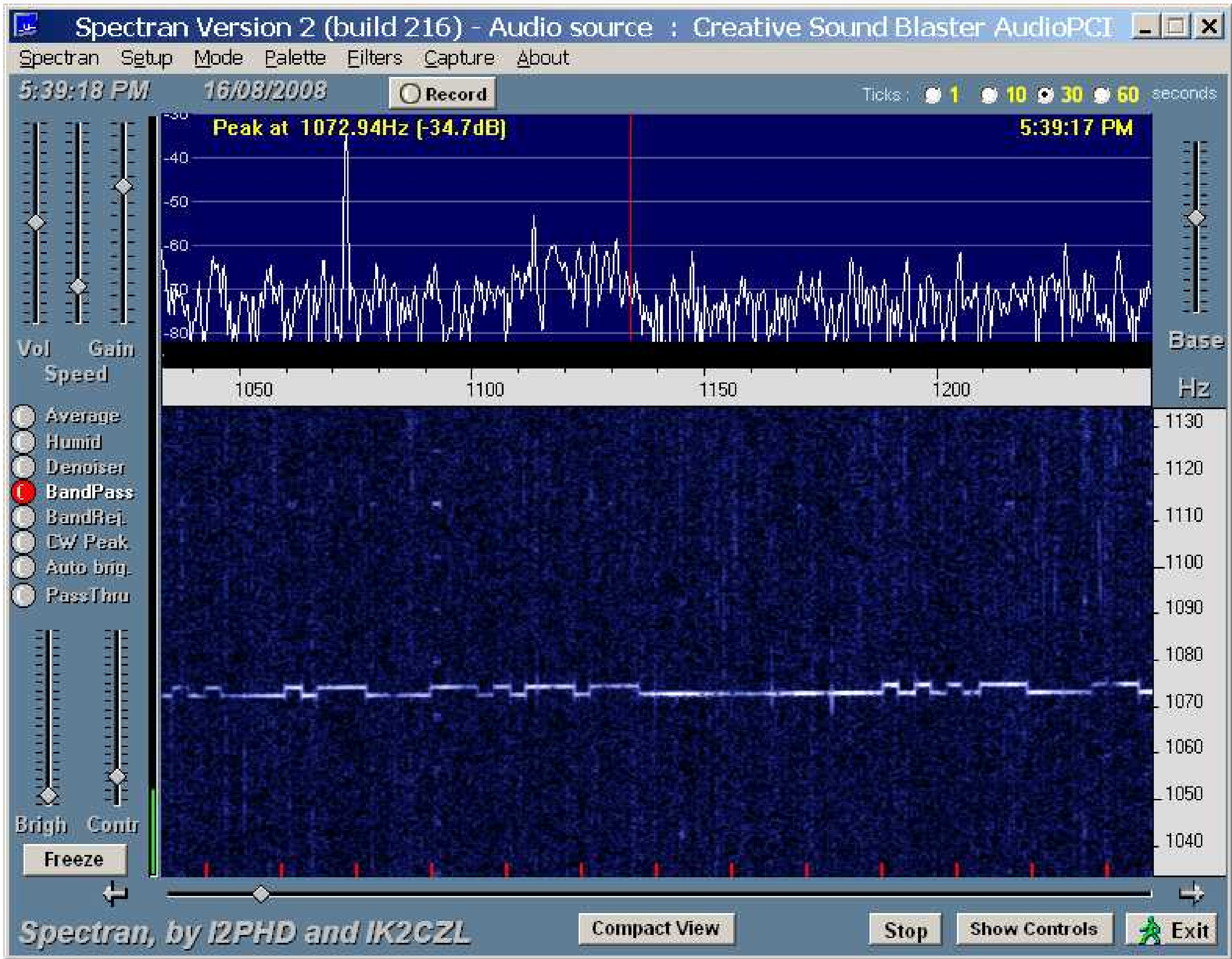
Vertical Antenna

The antenna has also changed, I've built a matching network to feed my 3-metre vertical used in the 80 metre beacon on 30 metres. I hope to eventually build a diplexer and matching network that can feed this same chunk of metal with both beacon TXs concurrently - but much design work remains before I can attempt that.

The matching inductor is 7.8 uH. A polyvaricon fine-tunes the match. Oddly enough the return loss into this simple network alone is quite good. This is suggestive of rather large ground losses... A lot more antenna work needs to be done, while I get excellent signals into David VK6DI and Bob VK7KRW's sites I am yet to be seen anywhere else by the online grabber network.

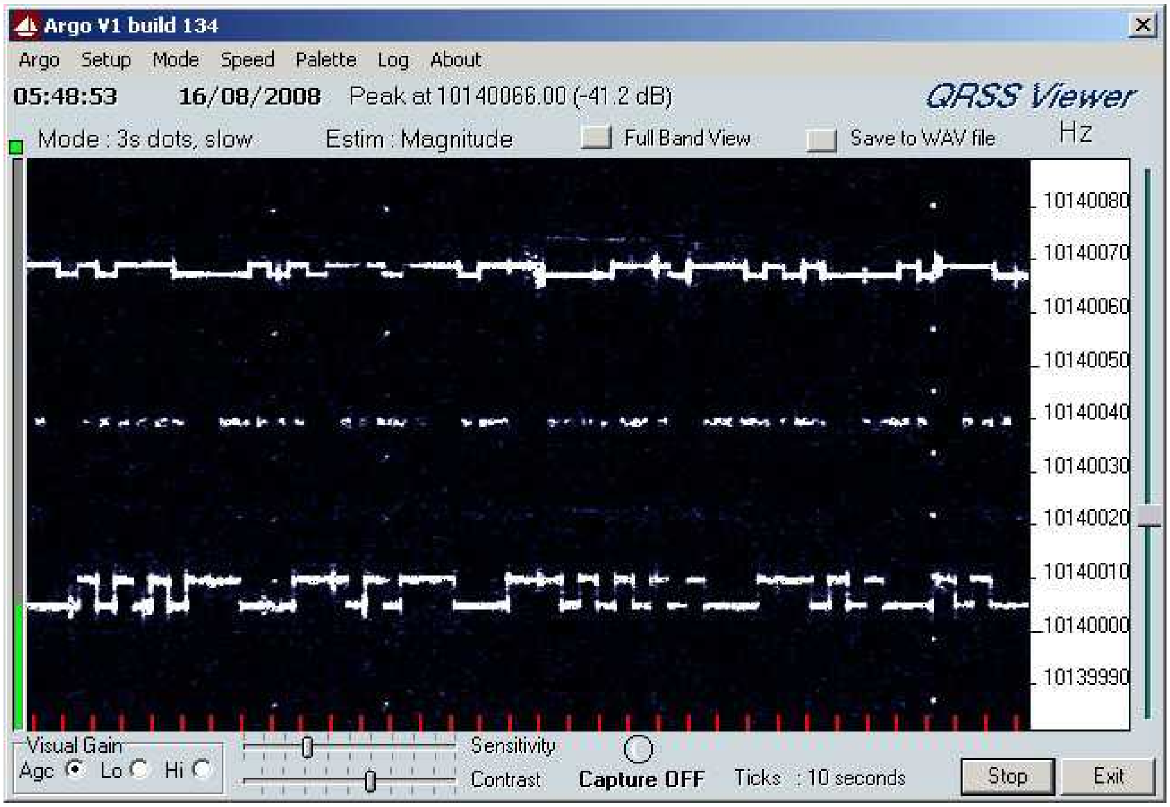
Results

David VK6DI has been able to copy my beacon in all its various states of construction and stability. One experiment in particular used just the 25 mW output of the driver amplifier. Signal to noise measurements from this test indicate I should be just visible above his noise floor running only 25 uW!



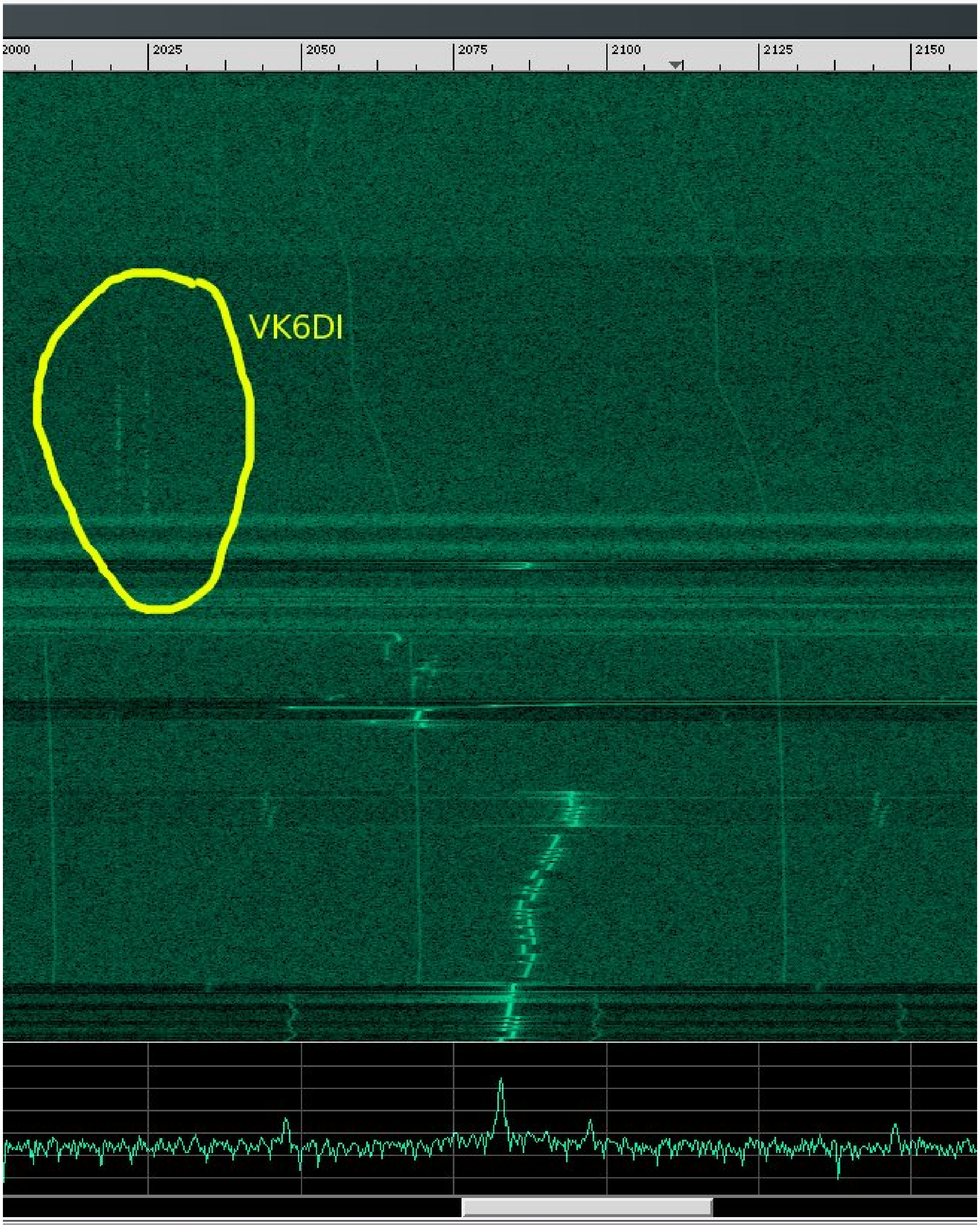
With the beacon output now at an easily measured ~30 dBm it is a simple matter to attenuate down for the real QRPp(p) experiments.

Bob VK7KRW has been seeing my signal as well. He is my first report from VK7, including the 80 metre beacon experiments. Next time I fire up the 80 metre beacon Bob will listen out for it as well.



QRSS Reception

My attempts to receive QRSS have not been as successful as my TX work. My noise floor is *horrible*, combined with poor antennas this limits my chances. I did accidentally see VK6DI's 500 mW signal during measurement experiments on my beacon.



2 comments.

Attachments

title	type	size
Oscillator Circuit Source	application/postscript	14.584 kbytes
Frequency Modulator Circuit Source	application/postscript	11.443 kbytes
Driver Amp Circuit Source	application/postscript	12.719 kbytes
Amplitude Modulator Circuit Source	application/postscript	11.658 kbytes
Power Amplifier Circuit Source	application/postscript	12.412 kbytes

Controller Circuit Source	application/postscript	12.063 kbytes

Parent article: 30 Metre QRSS Beacon.

30 Metre QRSS Beacon

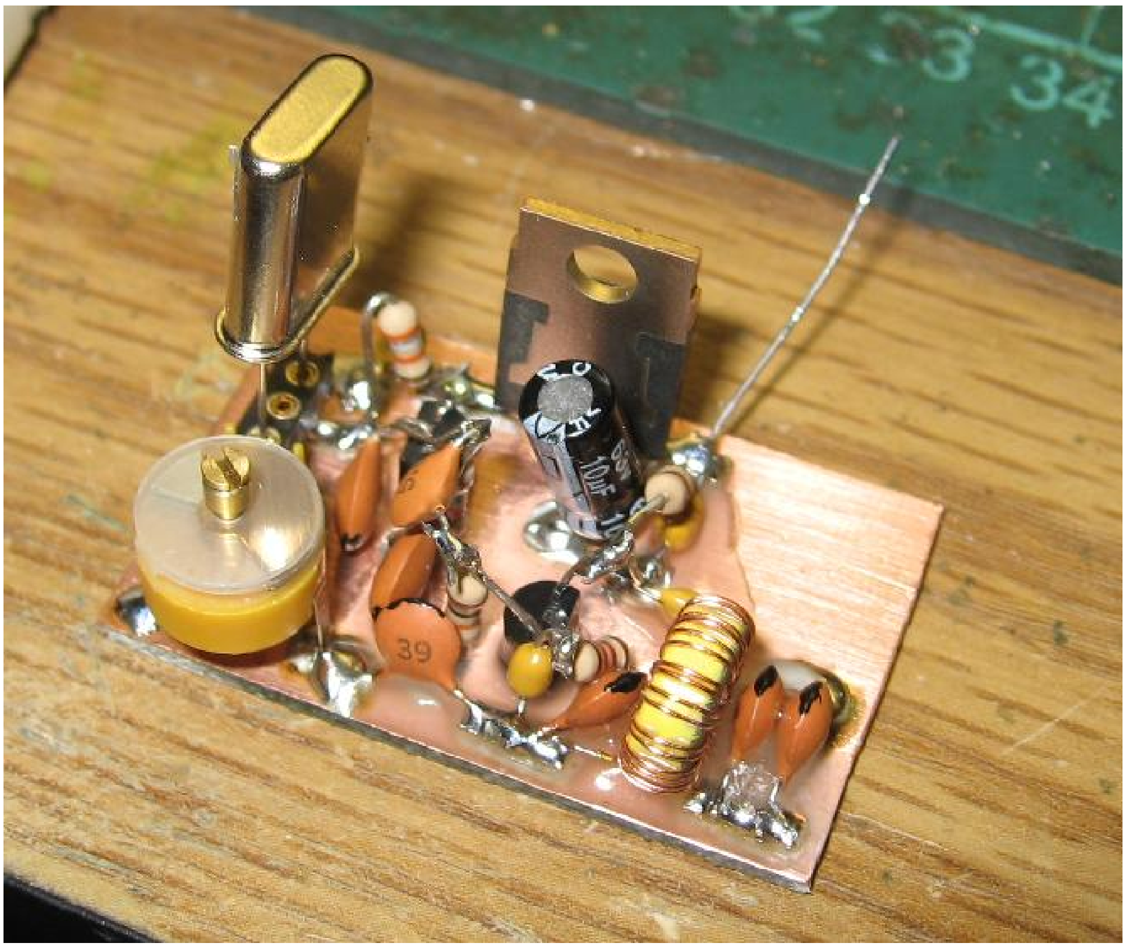
2008-08-10

This weekend I had decided would be "QRSS weekend", I've been fiddling with the idea for too long now, it was time for a strong effort to complete the project. As luck would have it, David VK6DI found my 80 metre beacon and added some extra inspiration to get my act together on a 30 metres beacon.

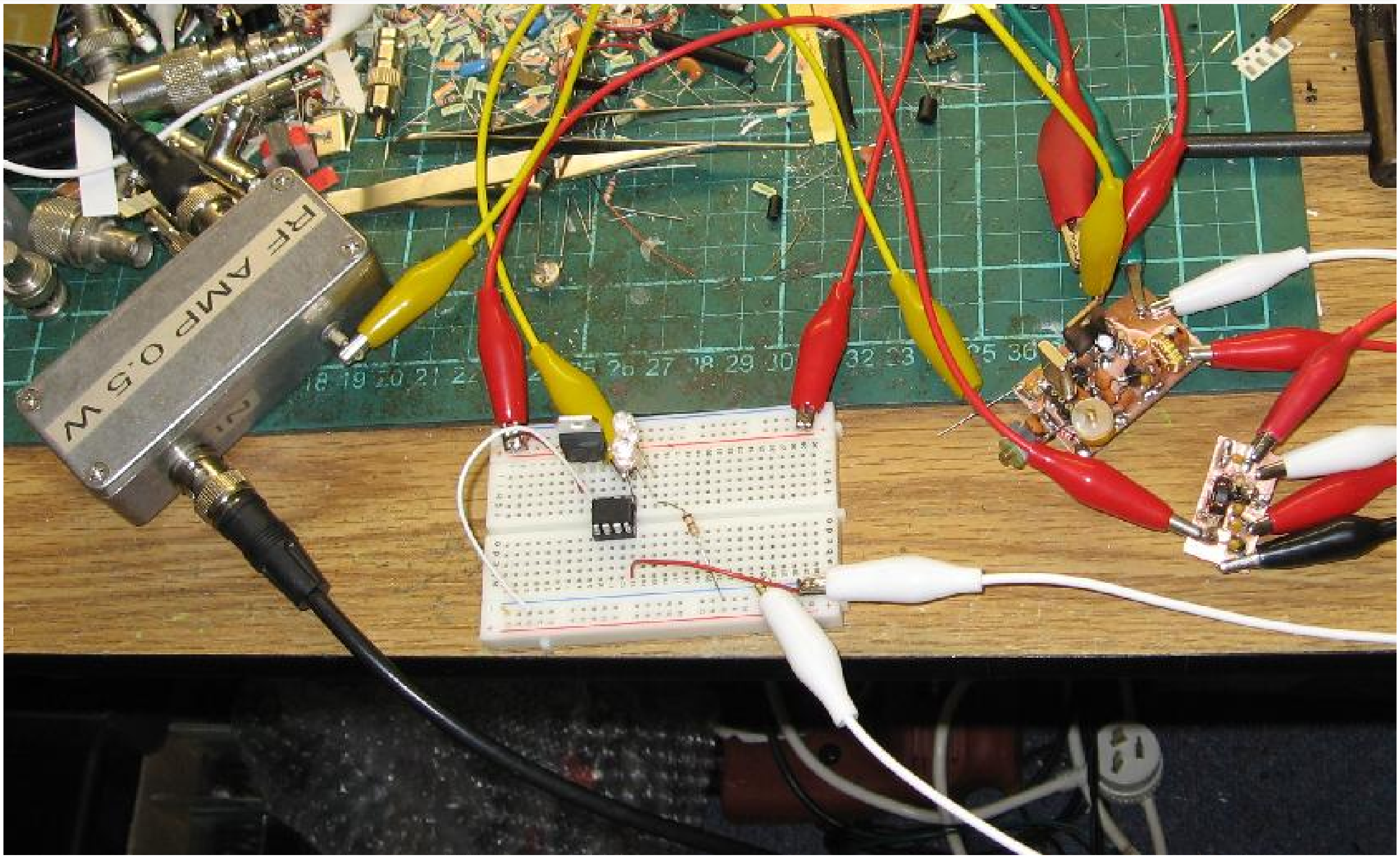
I ordered my 10.140 MHz xtals from DL6JAN. The arrived quickly, nicely packed - it was an easy process, I highly recommend him as a source for QRSS rocks.

The Transmitter

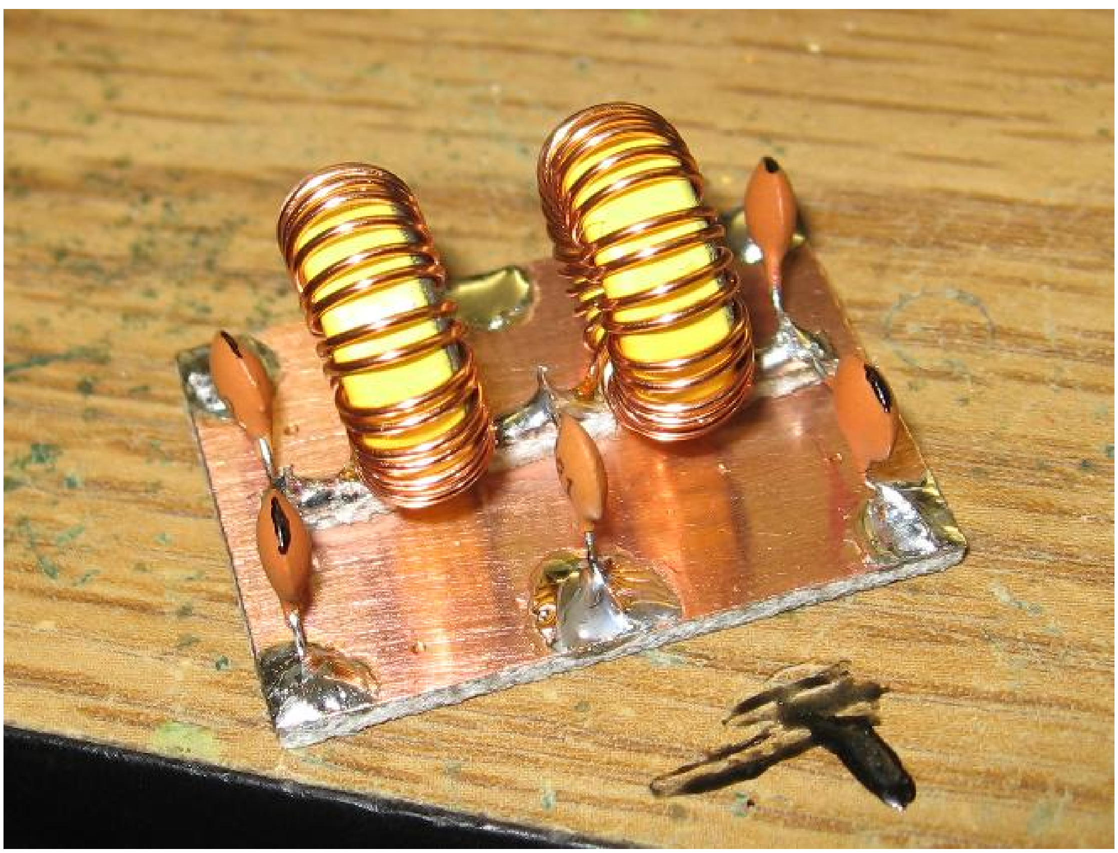
The oscillator is a conventional Colpitts, with an 8 volts, 3-terminal regulator for voltage stabilisation. The buffer is a J310 JFET source follower with a 10 k input impedance fed through a 5p6 cap, the output is filtered through a LPF and delivers about 900 uW into 50 ohms.



This is followed by a 2N3904 feedback amplifier giving about 20 dB of gain. This then drives my old SM0VPO QRP RF amplifier as a power amp.



A small low-pass filter follows to clean up the output suitable for delivery to the antenna. About 29 dBm is delivered into 50 Ohms.



The Keyer

The beacon keyer is a Atmel ATtiny13V running very simple code. It offers two outputs, one for CW keying (currently unused), and the other for FSK. The beacon CW idents three times at 10 WPM between the QRSS6 FSKCW idents. A small trimmer in the oscillator circuit is diode switched by the beacon controller to pull the oscillator an adjustable amount.

The Antenna

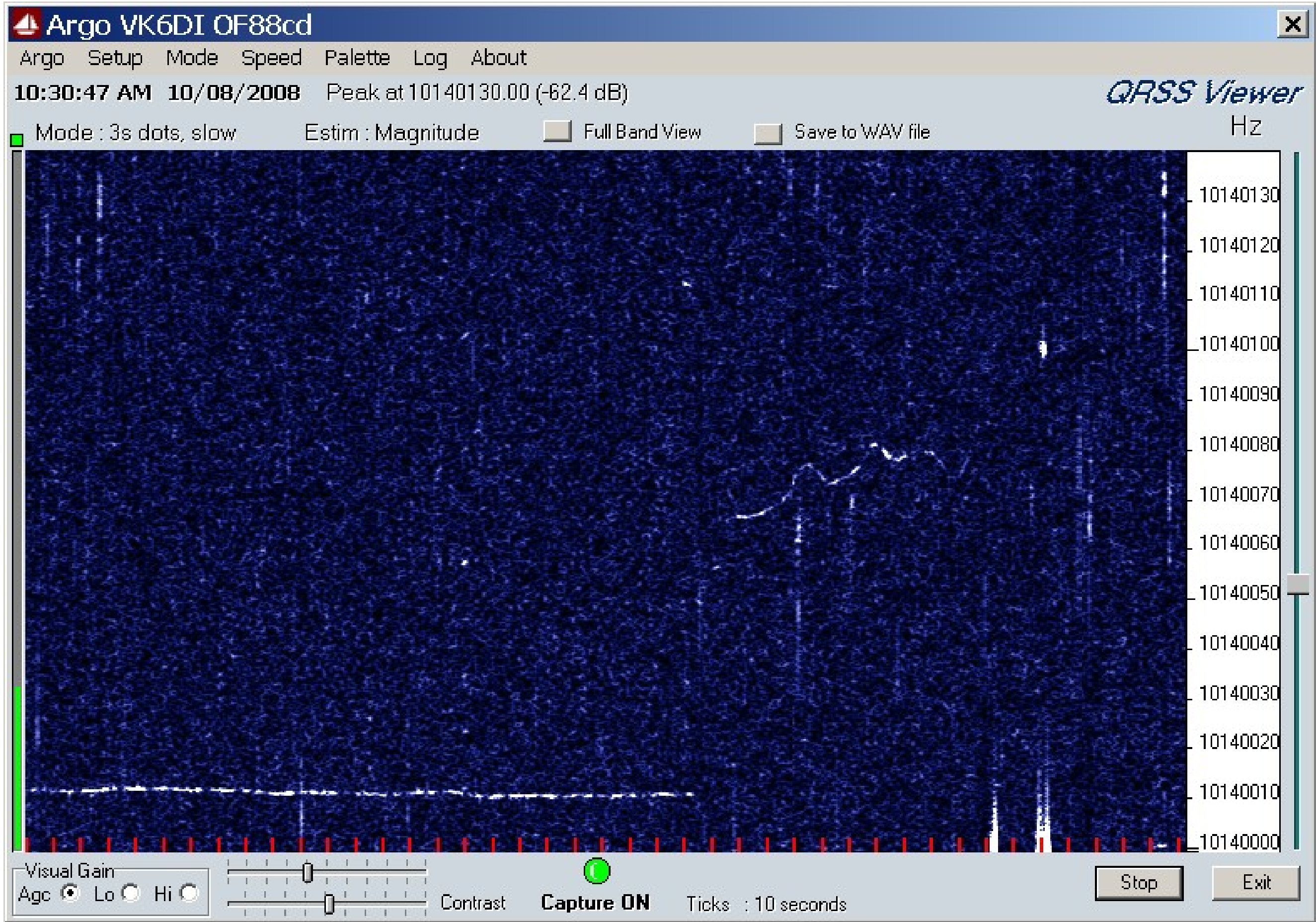
The antenna took much of Saturday to setup and debug. It is a loaded inverted V. Two ~27 uH coils allow the ~2.5 metre arms to be resonant on 30 metres.

Precise tuning is achieved by a Z-match at the feedpoint.

The antenna is still very much work in progress, but looks like it will work OK for now. Return loss can exceed 40 dB, but seems to drift with the temperature of the day (can be tuned back up again). I suspect the loading coils are drifting around a little as they change shape with temperature. I'll have to lacquer the turns in place, but I am cautious about increasing their distributed capacitance and causing SRF and Q-reduction problems.

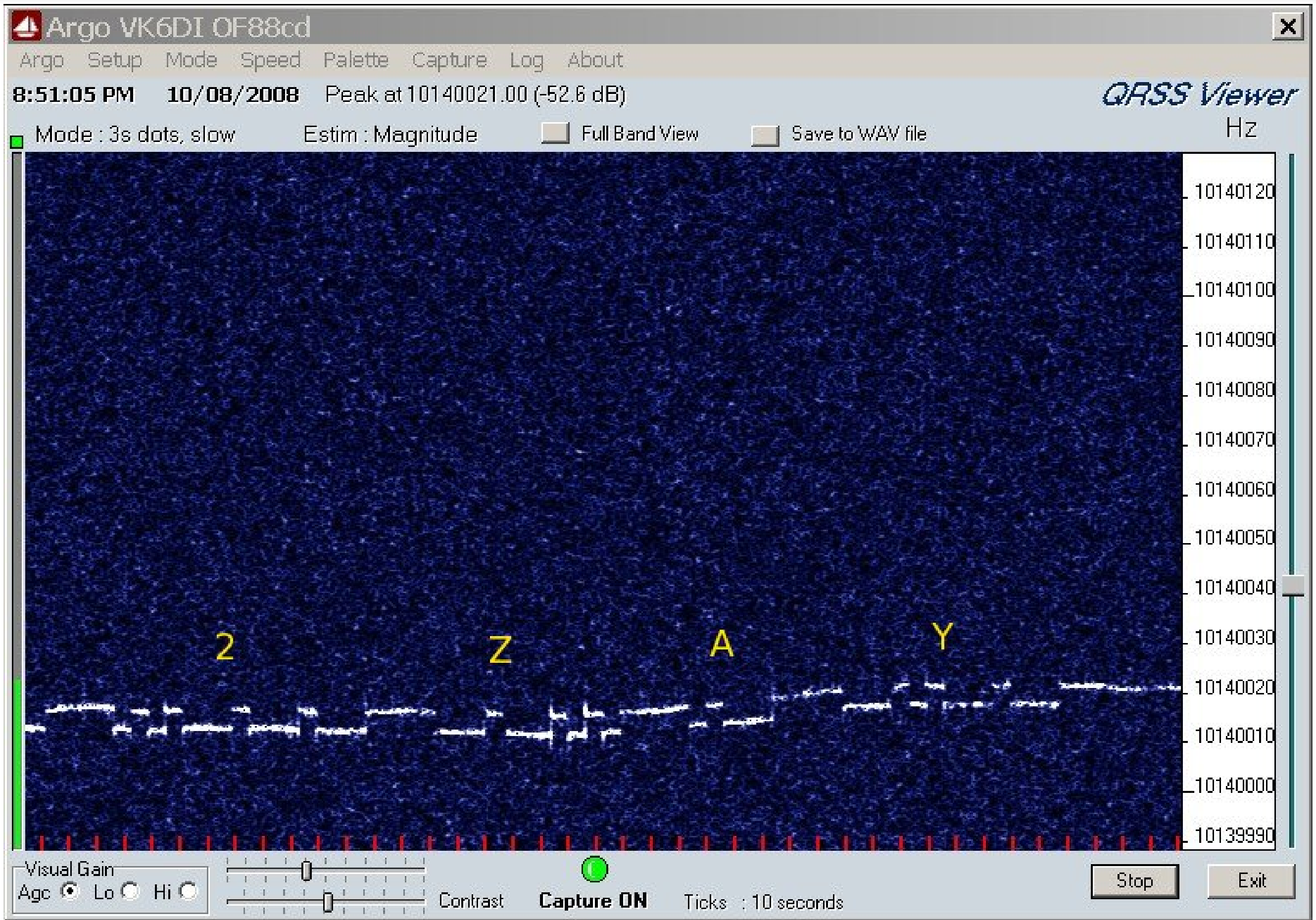
Results

David's grabber has been enormously useful during this development work. From the initial lash-up on solderless breadboards into the newly constructed antenna I've been able to see my wiggly signal on his grabber. Here is a shot of my first 250 mW signal through the antenna bridge while I was still playing around with the Z-match. The relatively stable signal is also mine, which I then QSYed to prove to myself it was really my signal I was seeing, that's the wiggly bit, I was using the C-jig to tune the xtal oscillator by hand.



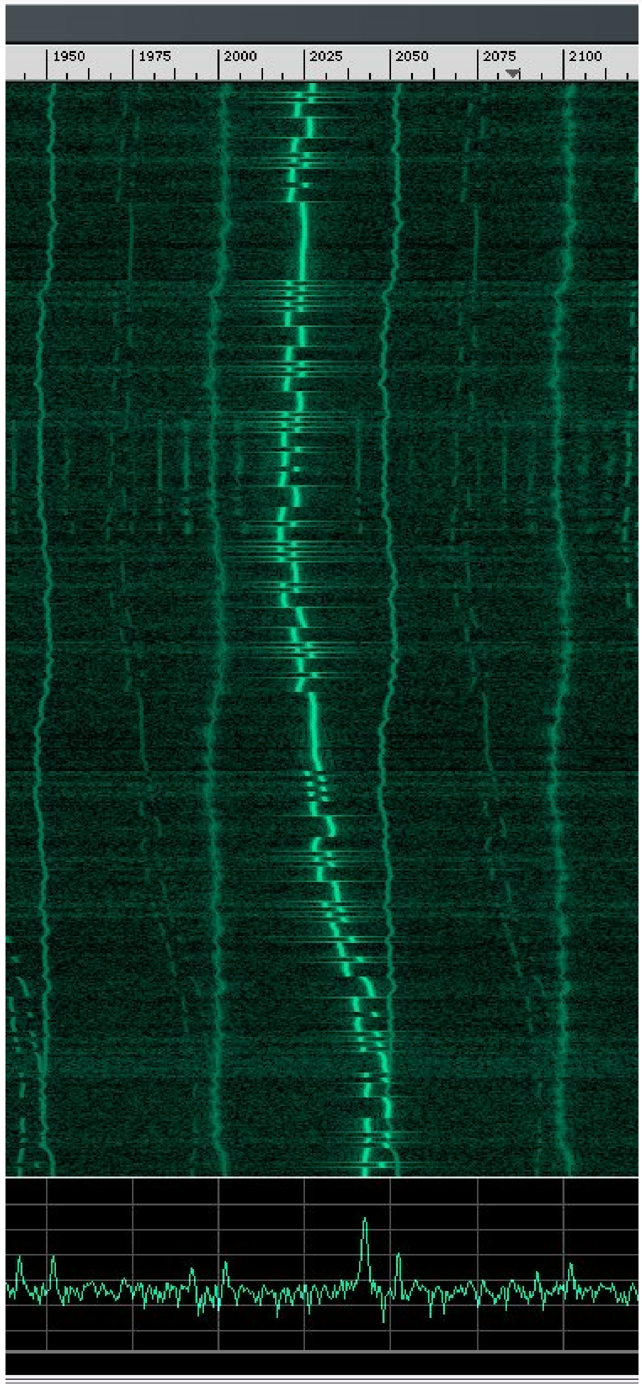
That's less than 1/4 of a watt from 3300 km away!

Improvements through the day lead to good signal reception at David's end.



Stability is still a problem, as the TX isn't boxed the air conditioning in the lab is causing the oscillator to drift around. I have some PTC thermistors that should make good oven heaters for the final assembly, I figure a nice diecast aluminium box will do the trick, with its larger mass and thermal inertia providing improved stability. Load variation frequency stability is excellent BTW, the JFET buffer and extremely conservative gain distribution gives good reverse isolation.

I've been monitoring the signal locally using my FT-817 and baudline running a 16384 point FFT.



This isn't really optimal for QRSS visualisation, but gives me a good idea of my shift width, centre frequency and stability. Also, I found using my new 30 metre antenna into the same setup I could easily see many of the signals David can, in particular a stable carrier near 14.140000 MHz that seems to come and go. I may have to build my own grabber RX...

All in all, the results are very encouraging. I achieved an enormous amount of work in only 2 days, from building the antenna and Z-match, through to the various TX modules and software for the beacon. There is still much to be done however, I need to box and stabilise the beacon, build a dedicated 1W output amplifier for it rather than using the boxed test amplifier, and fix up the antenna in a more permanent manner, in particular water proofing the Z-match and fixing the end-insulators for the dipole arms. I'll have to post the technical details too, circuit diagrams, etc. Next weekend... :)

4 comments.

Updates

2009-03-06: Hellschreiber QRSS
I implement sequential multi-tone Hellschreiber modulation in the 30 metre QRSS beacon.
2009-02-24: 30 Metre QRSS Beacon Calibrated
I finally sit down and calibrate the front-panel controls of the QRSS beacon.
2008-08-16: 30 Metre QRSS Beacon Updates
I complete and box-up the QRSS beacon, and experiment with a vertical antenna.

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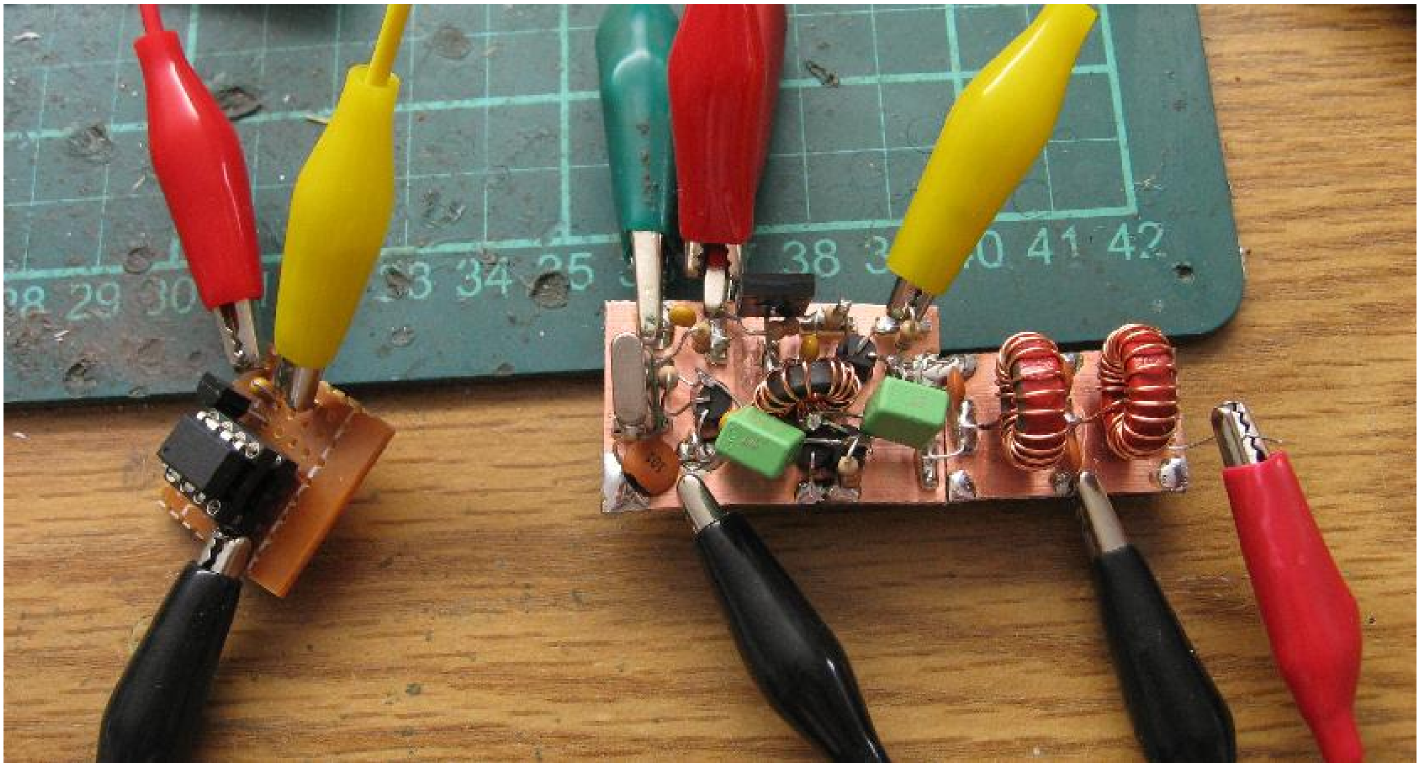
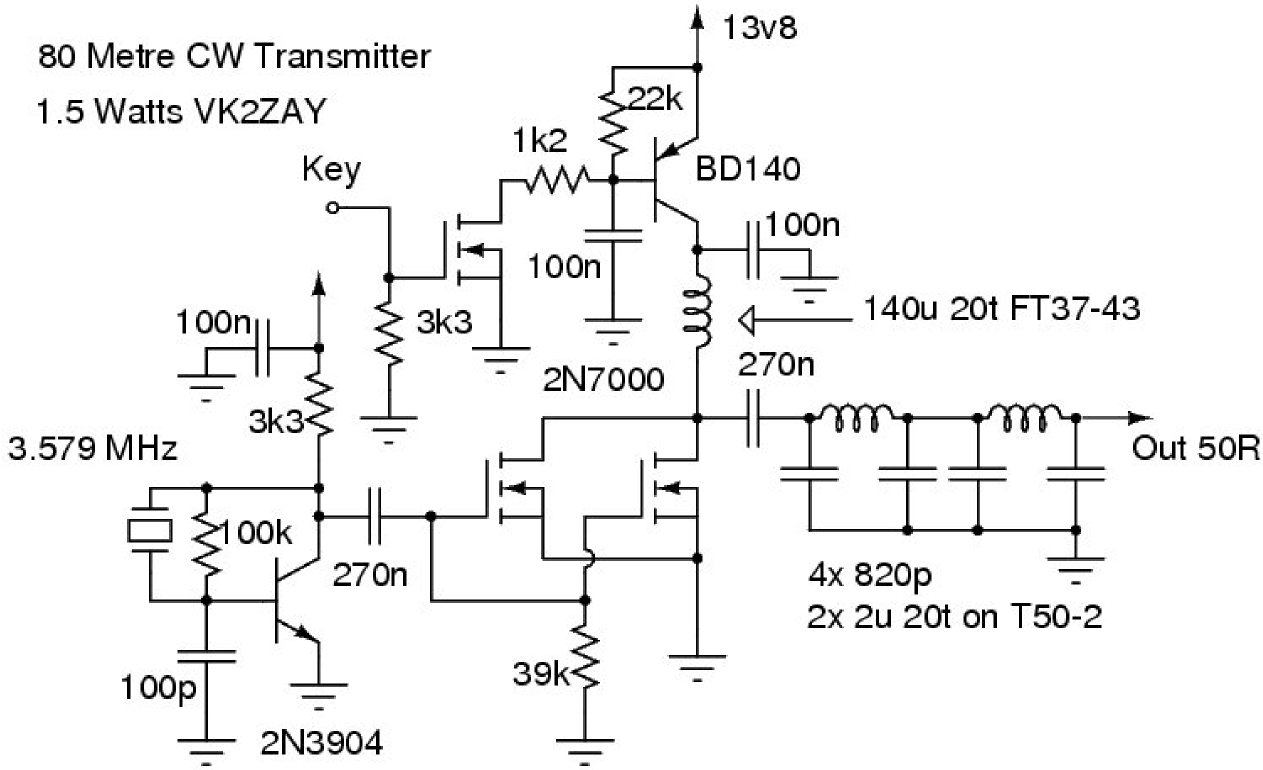
80 Metre CW Beacon

2008-06-21

The local Homebrew Group has been talking about Peter Parker VK3YE's Carnegie Communicator project in Lo-Key. The general design of the circuit (based on the old "Oner" CW transceiver) lead in the usual round-about way to build this CW beacon. OK, so how does a top-band AM transceiver lead to a Morse beacon? Well, inspiration is a complex thing, and with the PSK beacon stuck in phase jitter hell, a CW beacon sounded like a good project to initially test the waters with.



The design is very brute-force and simplistic, closely following the old Oner design. A Pierce oscillator drives a FET output stage with a keyed drain and an output filter. The output is loaded directly at 50 Ohms with no impedance transformation, limiting the output power to ~1.5 Watts from a 13.8 Volt supply when you consider the saturation voltage of the BD140 keying BJT. I tried several output devices, including IRF510 and VN10KM, but settled on a paralleled pair of 2N7000s which provided the best performance from the limited drive. A single 2N7000 will work and produce slightly more output power as the drive sees only half the capacitive load, but the device will run stinking hot and is being driven outside its safe working area. Two devices get warm to the touch and output about 200 mW less, but will probably last forever. The IRF510 on the other hand is under-driven in this circuit because of its much larger gate capacitance. The output with an IRF510 is still OK, and if its all you have it will work and give a little under a watt out for about the same drain current (~210 mA). With a little more than 1.5 Watts out, the efficiency is horrific at only about 60%. Modification of the output network to run in class-E could improve this towards 95% and the output devices would run much cooler, one 2N7000 would probably be fine. The 60 volt Vds limit of the 2N7000 gives a limited safety factor in this mode of operation however.



The crystal is an NTSC colourburst one from the junkbox, the output frequency is around 3.57867 MHz, but the crystal isn't oven-controlled so it will probably drift around a bit. Please send me a reception report if you hear it!

The keying is performed by an ATtiny13V. A small board holds a socket for the microcontroller a LM78L05 regulator and a decoupling capacitor. The active-high output of the keyer is used to drive the keyline through an extra 2N7000 pull-down. The microcontroller software is available here.

The "backwave" (key-up output power) is suppressed only about -46 dBc, which may prove to be insufficient. The backwave output power is of a similar order of magnitude as the total output power of some of Michael Rainey's beacons! Of course it is still very much QRP, and currently I am loading up my 40 metre end-fed dipole using 18 turns on an FT120-43 and my end-fed coupler which is just a terrible antenna for 80 metres so the actual radiated power is probably quite small. I'll probably build a loaded vertical with top-hat for this beacon if I keep running.

6 comments.

Attachments

title	type	size
Transmitter Circuit Diagram Source	application/postscript	15.456 kbytes

Updates

2008-08-03: Beacon Reports
Summary of the reports received for the 80 metre beacon experiment.
2008-07-13: New Beacon Antenna
I finally rig up a vertical antenna for my 80 metre CW beacon.
2008-06-29: More Beacon Work
I put the 80 metre beacon in a box and do some more work towards an antenna for it.

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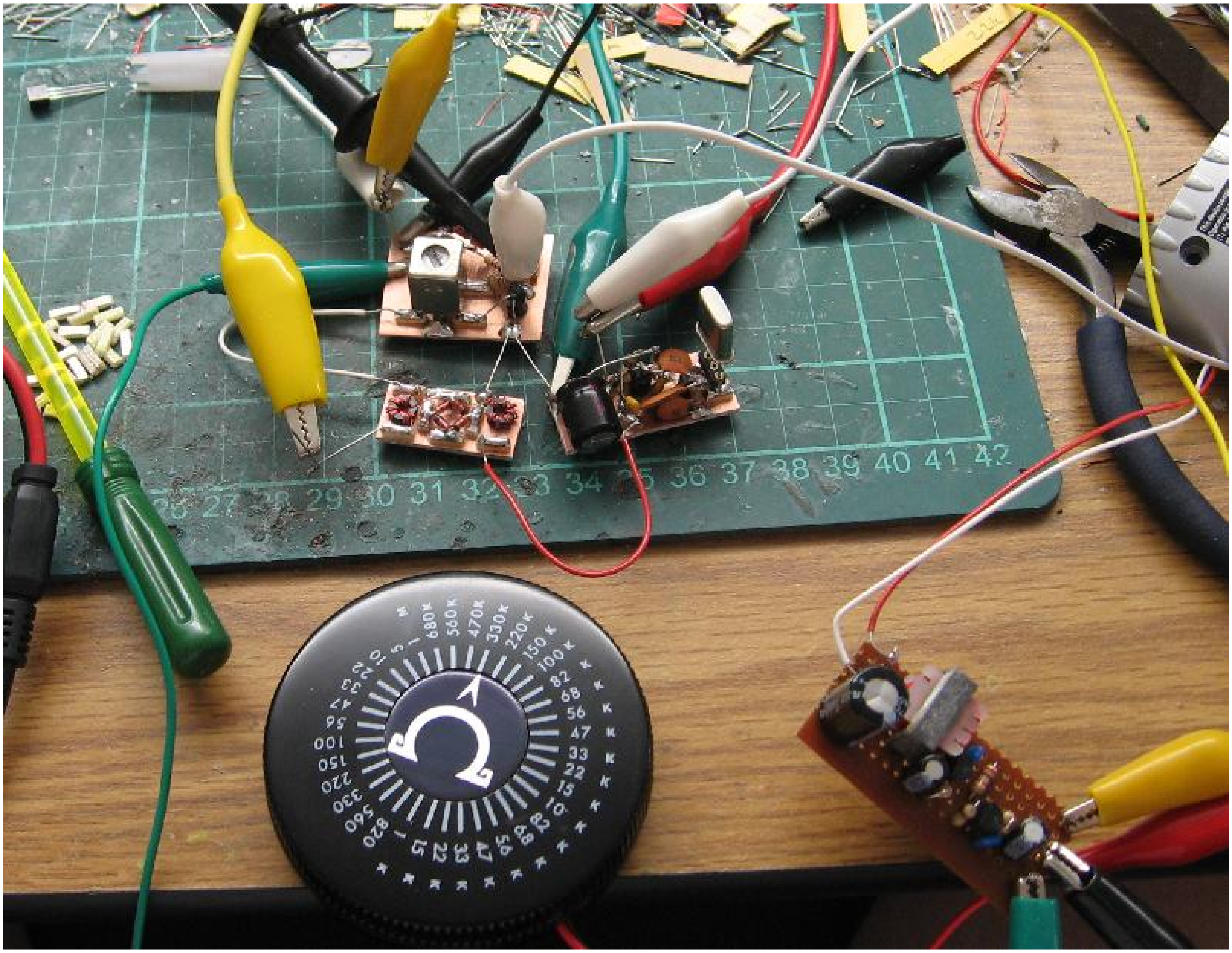
A Working Receiver

2007-02-17

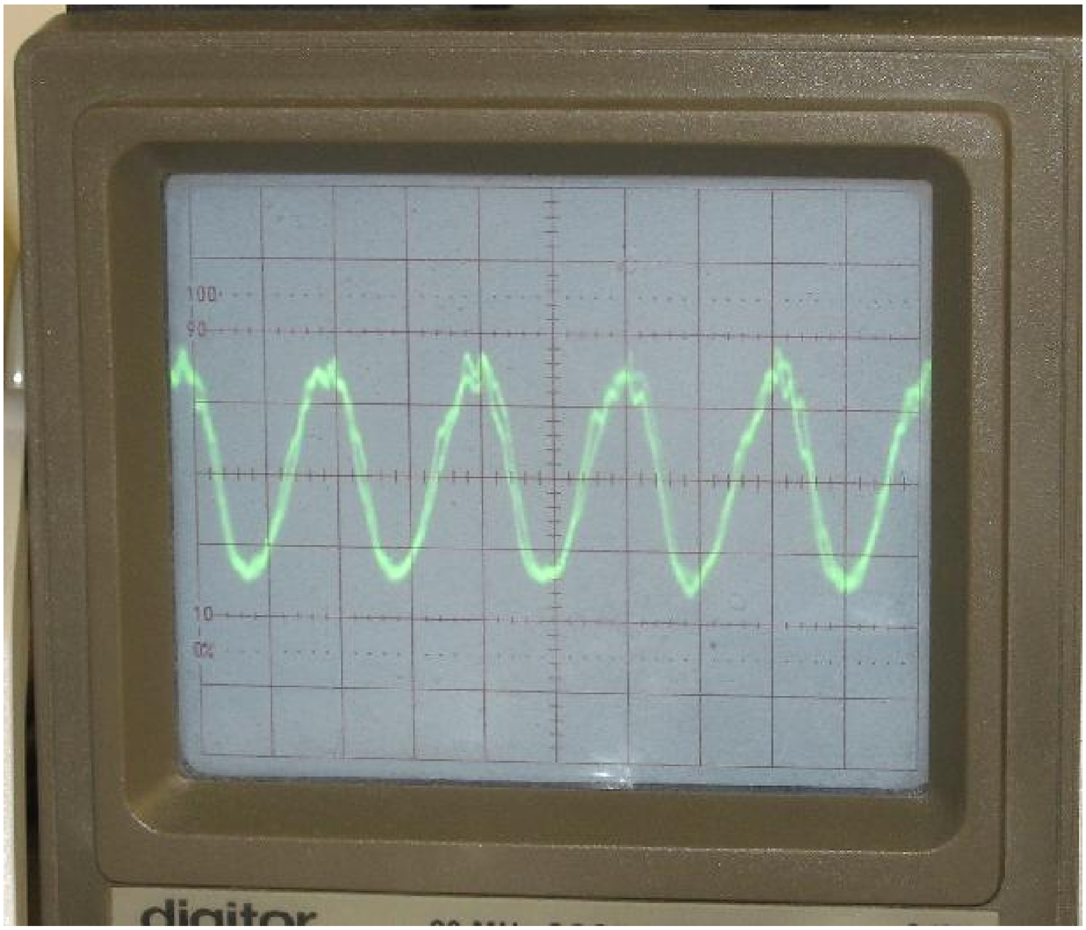
I completed a basically working AM receiver using the IF building-block from last week:



Note the lash-up with a 3.2768 MHz crystal oscillator, and the a two transistor veroboard AF amplifier I often use while prototyping. The resistance wheel is just acting as an attenuator for the AF signal path.

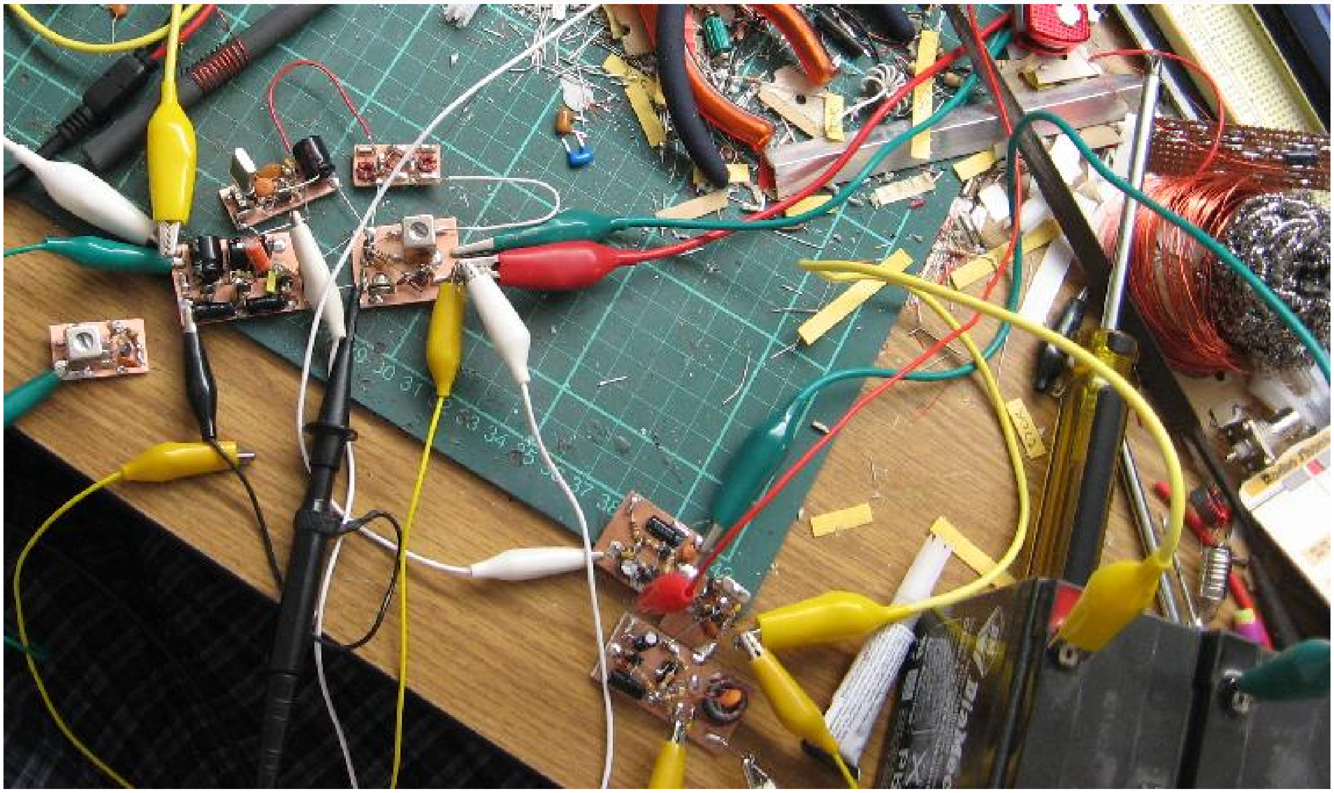
Some FT23-43 ferrite toroids arrived during the week from Kits and Parts. These tiny things allowed me to make an pretty small mixer without using excessively thin and difficult to manage wire, as I usually would when using ferrite beads at this frequency to get sufficient reactance (i.e. more than two or three turns through the bead means the wire must be very thin).

The receiver produced a noisy, but quite usable signal from about 10uV of RF at 3.68 MHz:



Finally I could use the AM transmitter to produce a test signal for the receiver. For this test, the TX was powered from a pair of 6 V gel-cells. The receiver was powered from my bench PSU. My VR-500 supplied the audio signal for the AM modulator, tuned to an FM radio station.

A dedicated AF amplifier was built for the receiver. I actually made it too sensitive, using a design I would normally use for direct conversion receivers. The output of the MK484 is high enough to make such extreme AF gain unnecessary. Removing the emitter bypass on the first stage offered acceptable gain, but a simpler amplifier with only two transistors would be sufficient. I also made the output class-A, with a 2N3904 standing quite a few mA - I may rebuild this module to something less of a hack, more efficient, and better suited to the mV output level of the MK484.



Note the small board with an IF can on it, this is a 455-ish kHz BFO oscillator for resolving CW/SSB. This doesn't work as well as a proper product detector, the injection level needs to be adjusted with varying signal strength, but the AGC makes a set level usable over a fair range. Higher injection levels de-sense the IF by activating its AGC. There is little way around this as the AM detector is buried inside the MK484 where you can't access it for BFO injection, and is simply the price you pay for such a simple IF circuit. That said, the BFO works fine, I was able to receive the ARNSW morse beacon on 3.699 MHz using this receiver and the BFO. Some success was obtained from injecting the BFO into the mixer LO port, requiring somewhat less injection level adjustment. I would like to avoid a front-panel BFO level adjustment, but a simple switched pot would be a practical solution if you don't mind the extra control.

Some VHF break-through interference was observed with the IF stage during testing. Vega FM at 95.3 MHz would be heard in the noise, extremely distorted. I assume the fairly long input lead from the MK484 to the IF can pad is picking this up, nothing else in the circuit changes the effect when touched. Shielding will correct this, but if I build this kind of IF circuit again I'll be more careful with the layout of this rather high impedance point.

As currently lashed-up the front-end allows anything into the mixer. This means it can harmonically resolve signals, for example, Radio Australia's monster signal on 6.020 MHz made it impossible to listen for ARNSW's morse beacon 3.699 MHz until after the shortwave station moved to another allocation for the day. While their respective IF frequencies where 100 kHz apart, the receiver selectivity was not sufficient to handle the enormous shortwave signal, some front-end filtering will take care of this. A ceramic filter in the IF path would improve the selectivity, or a Q-booster on the IF resonator.

By tuning around with the IF can, the receiver as-is makes a usable shortwave receiver. The AF amplifier can produce ear-splitting audio into headphones, and pretty room-filling audio using a matching transformer into a small speaker. You just slot in different crystals and tune around with the IF can, but doing so will eventually take its toll on the IF slug and its plastic threads. It would be a simple matter to replace the crystal LO with a VFO and tune that way. In fact, once I improve the selectivity I may build a copy to dedicate to SWL. The very trivial nature of the circuit would make it an excellent project for novices or foundation calls (or whatever we call newer hams now days).

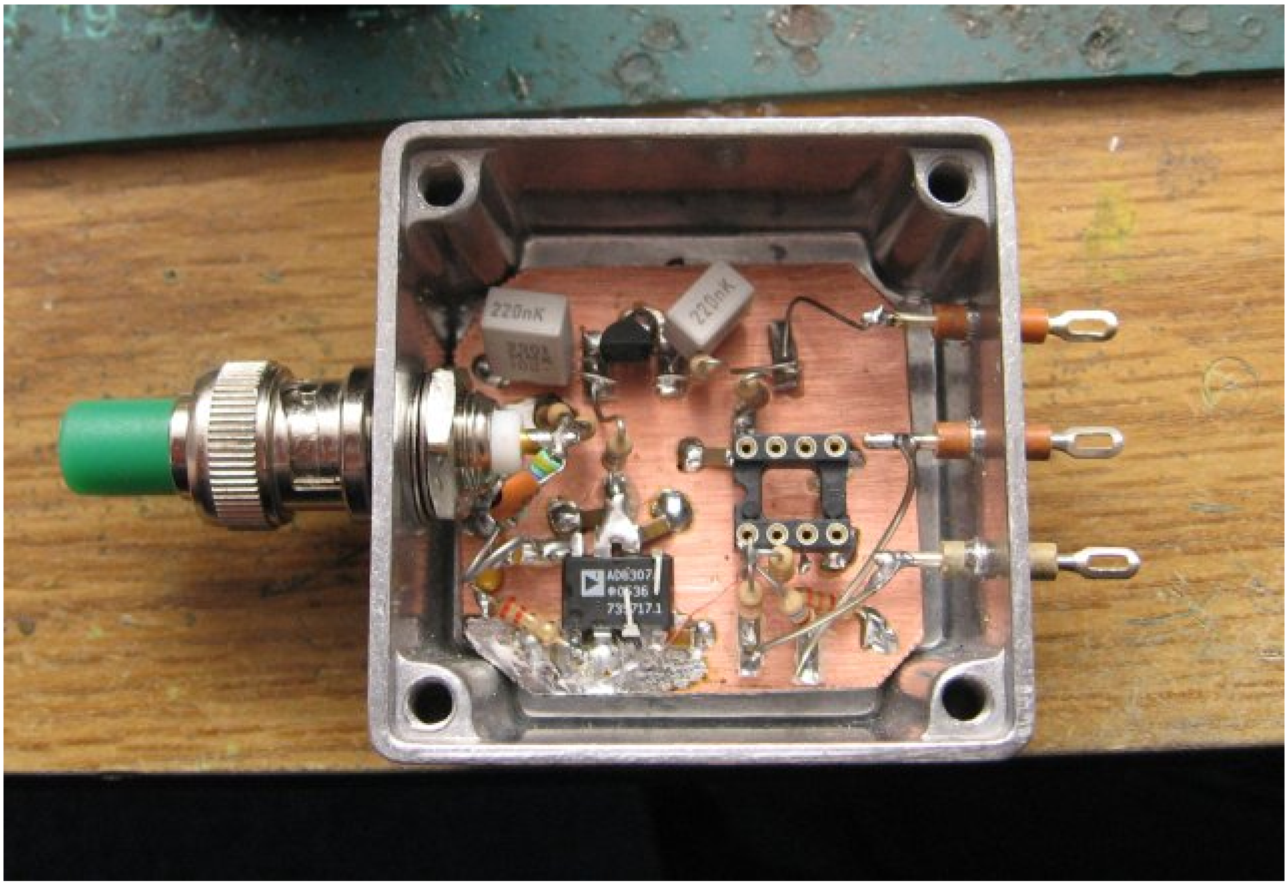
2 comments.

Parent article: "2007 80m Homebrew Challenge".

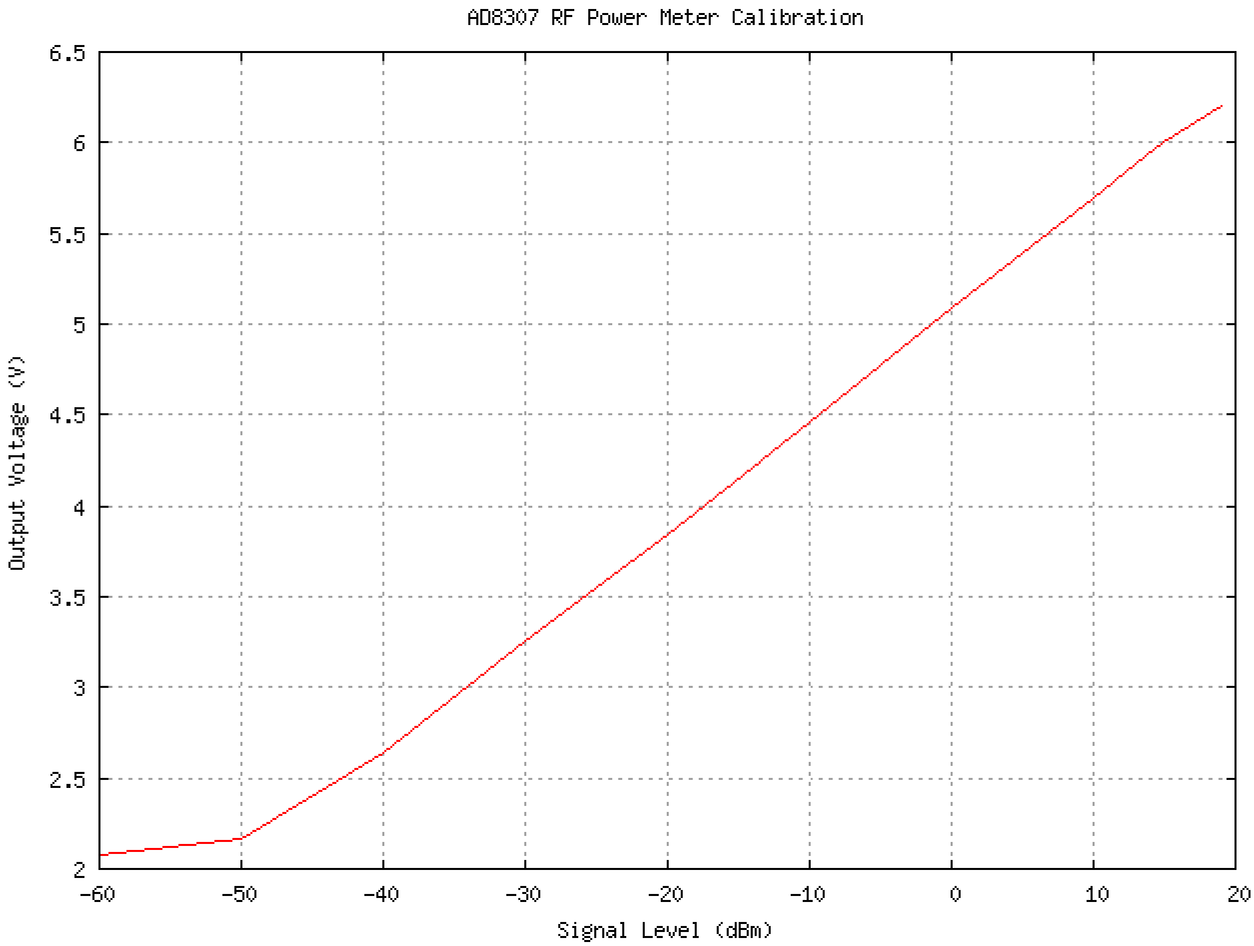
AD8307 RF Power Meter

2010-02-01

At the latest ARNSW Homebrew Group meeting I had the opportunity to finally calibrate my AD8307-based RF power measurement head.



Mark VK2XOF brought along his power and frequency reference equipment and gave me a bunch of calibration points.



Data points above 13 dBm were given using the generator out of levelling-loop calibration so the slight compression approaching 20 dBm is to be expected. The levelling off below -40 dBm however is not. I know the noise floor of the meter (dummy-load terminated) is about 500 mV DC output, -40 dBm is about 2.65 V out, suggesting wideband noise from the generator was swamping the lower level spot calibration signals.

Regardless in between the data is very consistent and lets me compute a "slope + intercept" calibration relying on the excellent linearity of the AD8307. The 0 dBm intercept is 5.09 Volts and the slope is 16.469 dB per Volt (60.7 mV per dB). Based on the 500 mV noise floor this equates to about -75.6 dBm, or about 80 dB dynamic range - as expected for an AD8307-based unit.

Frequency response wise, my use of leaded resistors means it maintains its accuracy to about 250 MHz, which is sufficient for my immediate purposes. The circuit design itself is the W7ZOI design from EMRFD, page 7.7, figure 7.13.

3 comments.

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Almost a Tesla Coil

2002-10-21

Over the weekend I had a chance to catch up with my electronics stuff which I haven't touched for ages, work has been nuts. I was sitting there building an inverter to drive a fluro tube, when I got interested in the properties of the primary and secondary windings, they were misbehaving, pulling the oscillator to one frequency, then another. I guess it was their self-resonance frequencies they were settling in, so curious as I was I wanted to measure them.

I tried a few ways, external drive coils with the CRO across the the coil, driven directly measuring the absorbed current with a in-line resistor, and probing with a dipper. It turned out that the primary's was about 1.6 Mhz and the secondary was about 50 kHz. The results of all methods agreeing with each other to within a percent or so.

All this fooling with inductors got me curious, so I put aside the project for a moment and started testing every inductor I could find. After finishing the junkbox full and promising to make a jig or tool to do this useful array of tests in the future really easy, I started winding my own with the left over wire from the inverter transformer. I think I learnt more about parasitics in inductors that night than ever before.

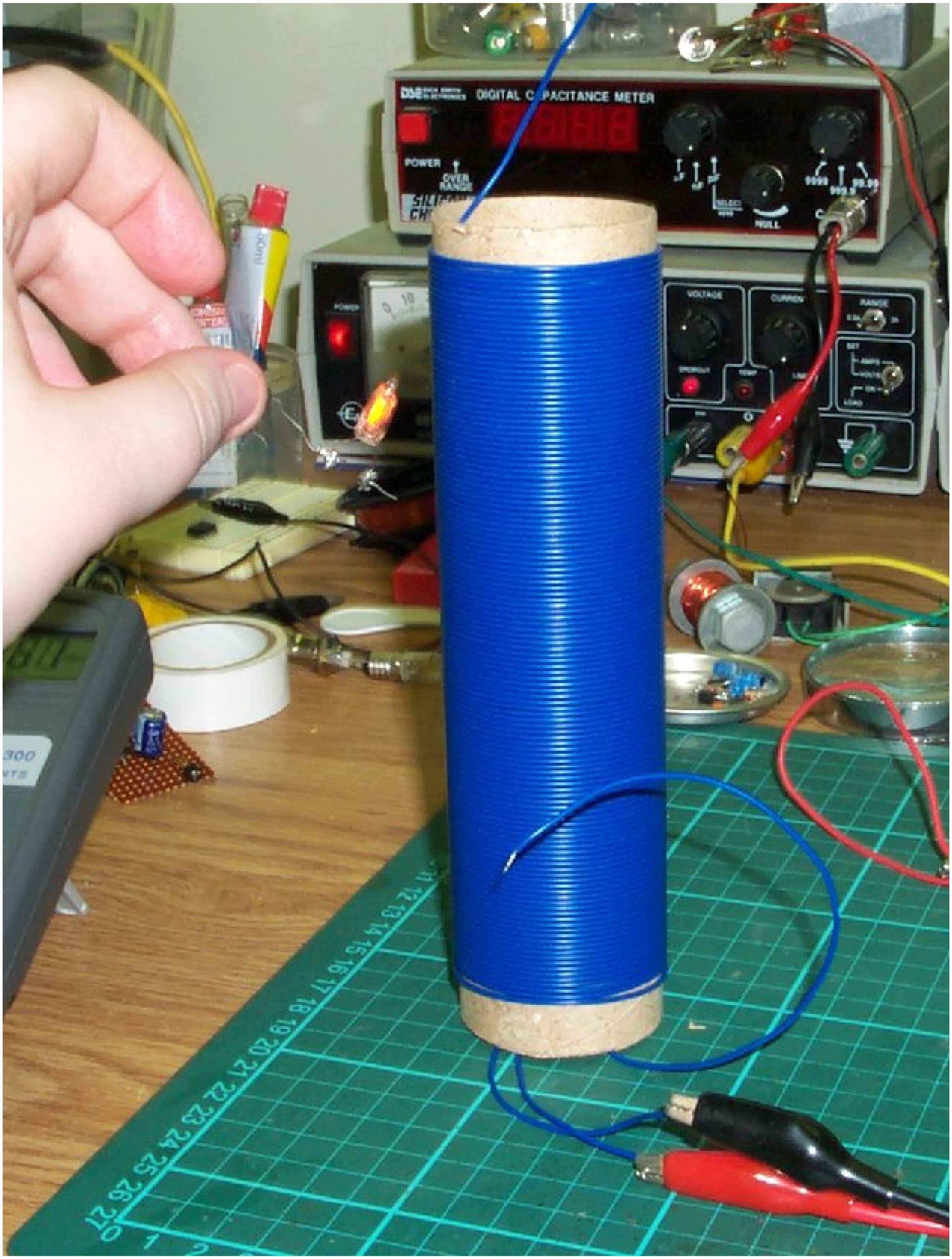
I've ended up with a simple measuring system, the square wave generator on my bench. Just injecting it into the inductor directly gives you almost all the information about an inductor you'll ever need, its resistance, its capacitance, its core losses. Try it sometime you'll never just grab a molded choke and whack it in the circuit without thought again.

So anyway, I decided to wind a long solenoid on a cardboard tube and measure its properties. A few turns at one end allowed tight coupling for injecting RF and seeing what happened. Here is the test set-up, my half-watt RF amp boosting the output of my signal generator:

The solenoid has a self-resonance of around 730 kHz with both ends of open. On grounding the bottom end, this falls to about 715 kHz kHz. Those numbers surprised me a bit, although the wire is normal multi-strand hook-up wire of very poor quality, $DEITY knows what its dielectric properties are. Its self-resonance harmonics are not 'perfect harmonics'. This is normal for a coil but somewhat surprising at first. My amp doesn't cover its fundamental, so I fed it at its higher overtones. Grounded is on the left, open on the right.

Note that there is no connection to the frequency counter. The huge field around this coil fed at resonance is penetrating the shielding of the meter and inducing RF currents directly in its input circuits. The frequency was

Considering the input power is only about 500 mW the field is very strong. Strong enough to light a neon bulb held near the coil. Tuning is touchy, my body capacitance pulls the coil around as I approach so I had to tune the generator while I was near the coil. Strange effects could be witnessed, like going too close detunes the coil so much the bulb goes out and multiple anti-nodes in the field along the axis of the coil. The photo doesn't really do it justice, the flash has washed it out, the neon was glowing very brightly, like a mini road flare. You can also see the PSU's drop-out light is on, the RF is upsetting its ripple detection circuit:



It is possible to strike a tiny RF arc across the output terminals, perhaps 1mm long at best. I would loved to

lousy neon that has seen better days in a ion counter.

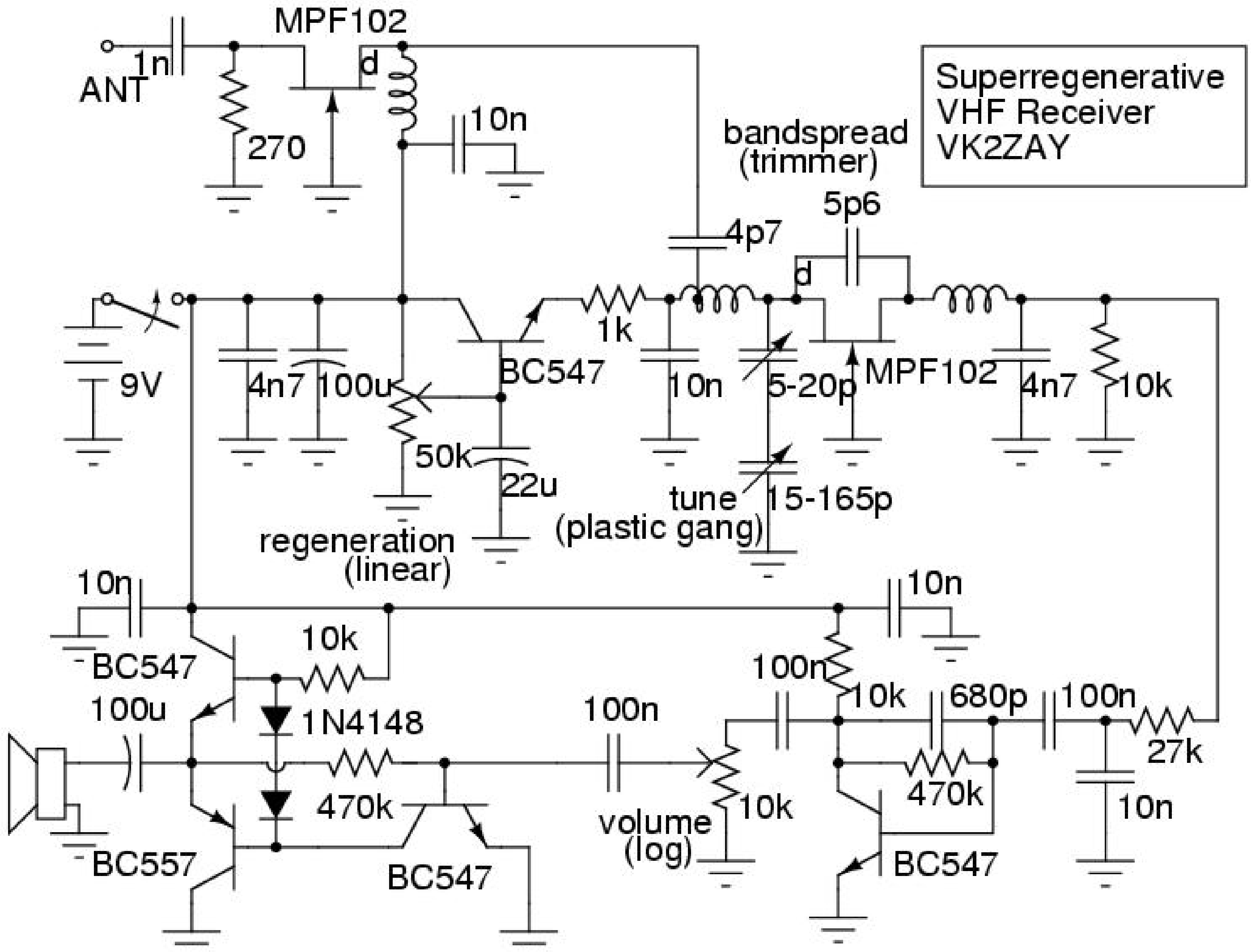
With more RF power I'd imagine I would have had a small Tesla coil. It was clearly a very high impedance at the top when grounded at the bottom. My poor little half-watt amp just isn't up to job though. It got stinking hot running into this load (I was abusing it too, running it from 24 volts to get more power). I would like to build a dedicated driver amp or maybe a power oscillator that uses the secondary as its frequency determining part, that would solve the detuning as I load up the coil approaching it. I've always wanted to build a Tesla coil, and a solid state one seems achievable now. It shouldn't be too different from making a lowfer power amp, or class-D transmitter, hell it is almost identical to the original inverter, complete with its parasitic oscillation problems.

1 comment.

Another VHF Super-Regenerative Receiver

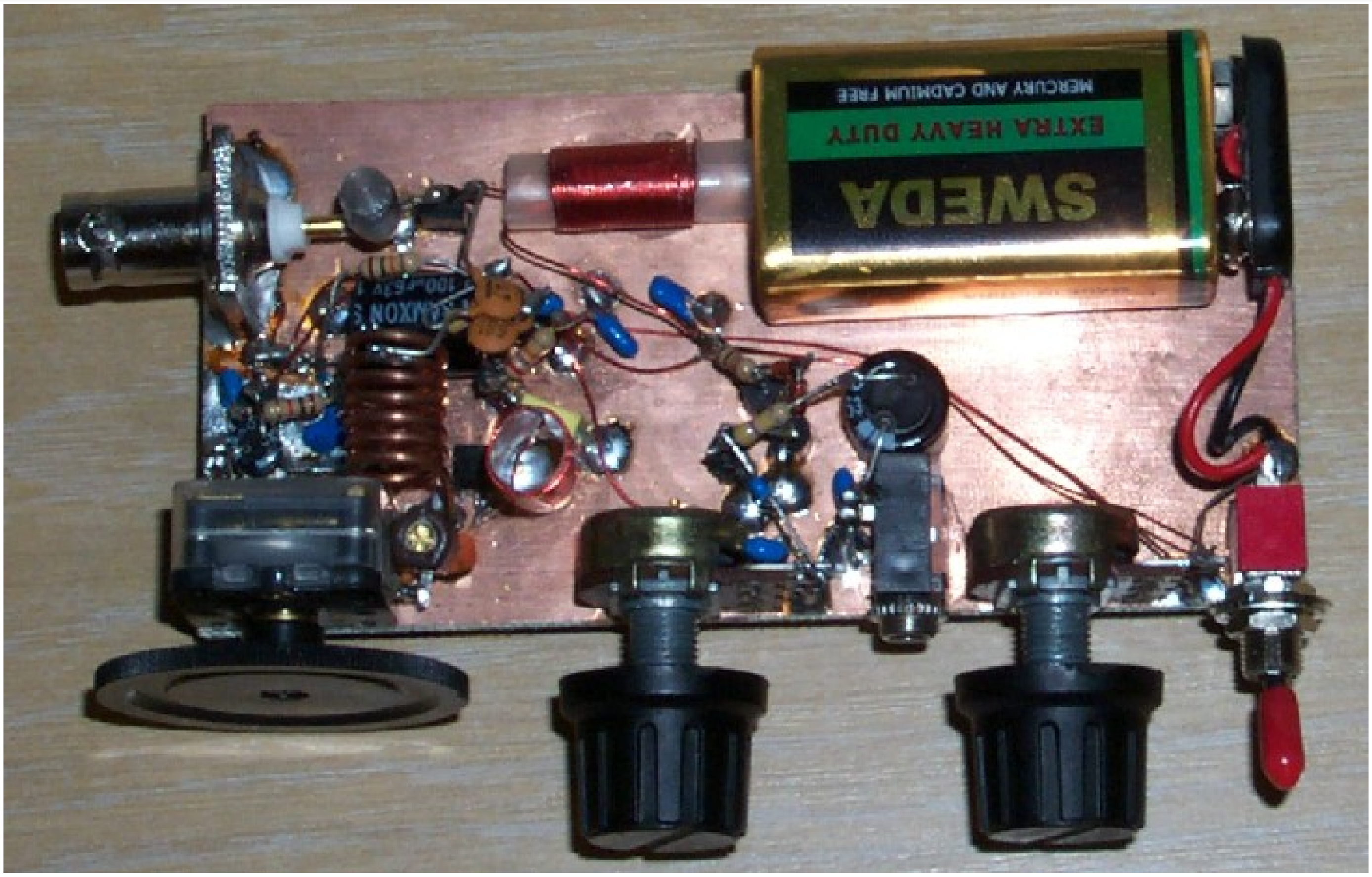
2003-05-10

Similar to my other VHF Super-Regenerative Receiver this design borrows heavily from Charles Kitchen N1TEV's various published designs. The audio stage is my own design, and I spent a lot of time tuning the component values for the FM broadcast band.



The three inductors are mounted orthogonally with respect to each other to minimise cross coupling. It isn't perfect, they are all in each other's near field and are not co-incident (obviously!) so there is some interaction, but it is greatly reduced compared to mounting them parallel, right alongside of each other. It is important to minimise local oscillator leakage back out the antenna, but as the entire board isn't screened the effort may not actually be worthwhile.

The low impedance current source supply for the regenerative stage improves performance over the usual 5 k pot regeneration control. It also reduces the current consumption of the entire circuit by about 2 mA, the regenerative stage pulling less than 3 mA max. The RF isolation stage by comparison pulls 3-4 mA. The circuit oscillates nicely down to 5 or 6 V which is much better than the previous receiver which had problems achieving super-regeneration with a 9 V supply.



With a little bit of careful adjustment of the band-spread trimmer and the main oscillator coil I was able to achieve 87-109 MHz coverage. It spreads nicely across the 180 degrees sweep of the tuning capacitor which is designed for linear tuning in commercial AM radios. The main tuning coil is seven turns of 1mm bare copper wire from a length of mains cable. The inside diameter is about 10mm, I wound it on my hobby knife's Aluminum rod handle.

The other two coils are wound on soda straw using 0.4mm wire. The thick transparent soda straws from Subway, which have an outside diameter of about 8mm, make excellent coil formers for light winding wire. The RFC for the buffer amplifier drain circuit is 30 turns, the coil in the source of the detector is 25 turns. Neither are especially critical, but the detector one may need some experimentation to achieve the best super-regeneration quench. It is important however, that their self-resonant frequency is well above the frequency of operation.

The audio output stage is fairly crude. The design could, in theory at least, suffer thermal run away. Adding a few tens of Ohm resistance in the emitter circuits would prevent this. I did not find it necessary however and the amp seems to work just fine with minimal cross over distortion for such a simple design. The diodes gently bias a few mA of standing current, ie class AB operation, but there is no bootstrapping so positive going amplitude distortion might be a problem at high output powers. All that said, driving 32 Ohm headphones the sound quality seemed quite good. Good enough compared to the quality of the audio recovered by slope detection of FM by such a simple detector.

The volume control pot could be placed as the collector load of the audio preamp, saving a capacitor, but I wanted to have one side of it earthed so I could solder it down to the board like the regeneration pot and the tuning capacitor. The same could be achieved by using a PNP device in the preamp instead, but I didn't think of that at the time. :-)

The biggest problem with using this receiver to listen to FM broadcast radio is beating of the quench frequency with the higher frequency stereo signal components. Quite frankly is sounds horrible and makes it hard to listen to stereo music broadcasts for extended periods. I can't see an easy way to fix this. Increasing the quench frequency so it is above the L-R sidebands and any SCA sub-carriers reduces the selectivity and gain of the detector significantly, and there are still mixing problems: The super-regeneration process is very non-linear and the IMD is pretty bad, aliasing the sidebands into the audible range.

Perhaps locking the quench at 38 kHz with a separate crystal oscillator would help? Any slight frequency difference beating should be below audio frequencies. The quench filtering could be better. This is a common problem with all super-regenerative designs I've found on the net. The single pole RC filter works 'well enough', especially when the output is an LM386 and for human consumption. However the output stage I use works to many hundreds of kHz so the inductance and mechanical response of the mylar speakers is relied upon to deal with the remaining leakage quench signal. Injecting the output of this circuit into a sound card or a tape recorder could cause problems with beating against the sample rate or the bias oscillator.

2 comments.

title	type	size
circuit postscript source	application/postscript	19.009 kbytes

Antenna and Weather Station Work

2009-01-13

A recent wind storm broke the support rope for my end-fed 40 metre dipole (also used as a random wire at times). While putting it back up I took the opportunity to do some other antenna work and put up the weather station my parents gave me in July last year!

For many years I've had a commercial discone antenna I picked up at the Wyong field day in a DSE clearance sale. IIRC it cost me about $40 which is *much* less than it normally retailed for. I've had it assembled on the balcony for several years, continuously getting in the way and spending most of its time upside-down collecting water in the mounting tube. Putting it up was long overdue. No idea what I will actually use it for, perhaps the airband - scanning was never really a big hobby for me.

Not exactly the ideal place for it, right next to my HF base-loaded vertical, but for now this is way better than sitting upside down. I chickened out on using the right-angle bargeboard mount in the manner it was intended after some back of the envelope calculations suggested the couple it would produce with an estimated wind loading from our infamous "southerly busters" was approaching the estimated mechanical limits of the bargeboard! Instead the bargeboard mount was used as a simple mast to attach the antenna to the balcony railing. At some point in the future I'll clean up this install and probably use a small bargeboard mount in that corner for other antennas.

I'm now out of coax lines to the balcony again, I only had sufficient coax to install three in the last coax run, it is now time to go and purchase some more and fill the remaining BNC feed-thru. I'll need another pair of wallplates to install more after this, and I doubt I can get away with too many more antennas on the balcony anyway. Eventually the HF vertical will have an remote tuning mechanism to cover HF and release one coax run currently used for 30 metres instead of just swapping the same run between 80 and 30 metres.

The 2 metre "flower-pot" vertical has been lashed to the railing in a very temporary manner for almost exactly a year now, it was also well due for relocation to a more permanent spot. I placed it on a large bargeboard mount with an offset. This raised it several metres improving reception of most repeaters. Unfortunately its RG-213 coax run is still partially water logged and must be replaced eventually.

The bargeboard mount also now hosts the weather station anemometer and wind vane assembly. While not an ideal position for such a device, this is the best I can do given the limited mounting options.

The weather station's tipping bucket rain gauge was mounted to the balcony railing, again not ideal but fairly unshadowed. The temperature/pressure/humidity and RF backhaul link module was mounted under the eaves in the exposed corner of the balcony to keep it out of direct sunlight but still offer good airflow (and distance it from the air conditioning condenser/compresser unit).

The 30 metre loaded inverted-V dipole remains in place, but unconnected. It should really be removed and replaced by something more efficient and actually useful, perhaps a 20 metre antenna for PSK31, but I hope eventually to run all HF through the vertical with remote tuning leaving more space for experimental antennas.

The work cost me a fairly high UV radiation dose to the upper forearms, enough to cause erythema but (so far at least) no pain or desquamation. I was wearing a hat and sunglasses, but no topical protectant. I suspect the majority of the dose was absorbed on the walk to and from the hardware store to collect the coach screws used to install the bargeboard mounting bracket, not during the actual work on the balcony. I got a *far* larger dose on the DX-pedition with Peter last year. The exposure is very minor compared to what I see many people on the beach take on a daily basis - salmon pink and pealing but still going out for more - they will no doubt regret those burns in time.

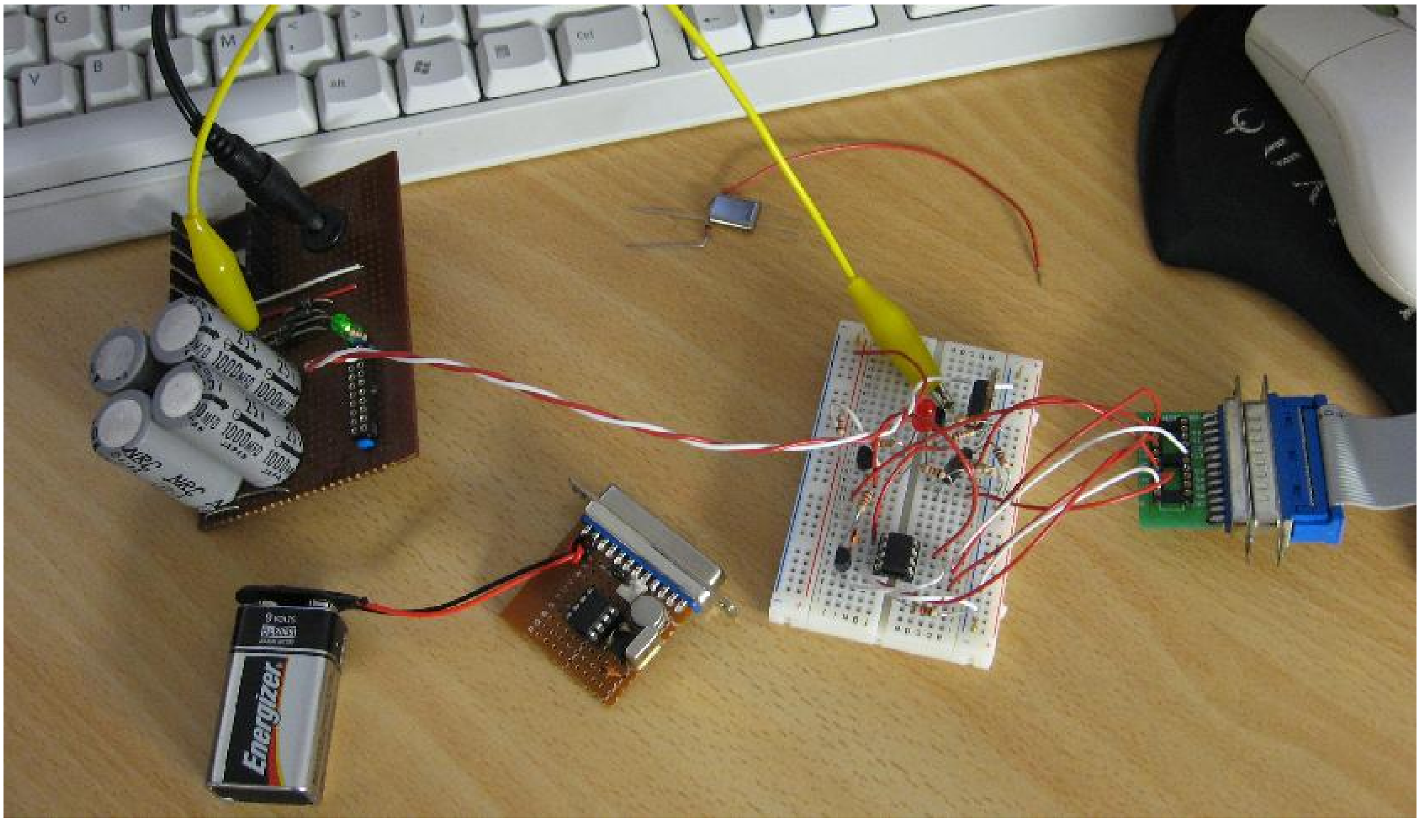
Leave a comment on this article.

ATtiny High Voltage Programmer

2008-05-03

This project was meant to be a quick hack to unbrick an ATtiny13 I stuffed up performing an ill-advised programming kludge upon. It actually ended up taking me all damn day to debug the programmer hardware... Initially I thought I had software problems, but it turned out to be clock bounce from the cabling causing me grief.

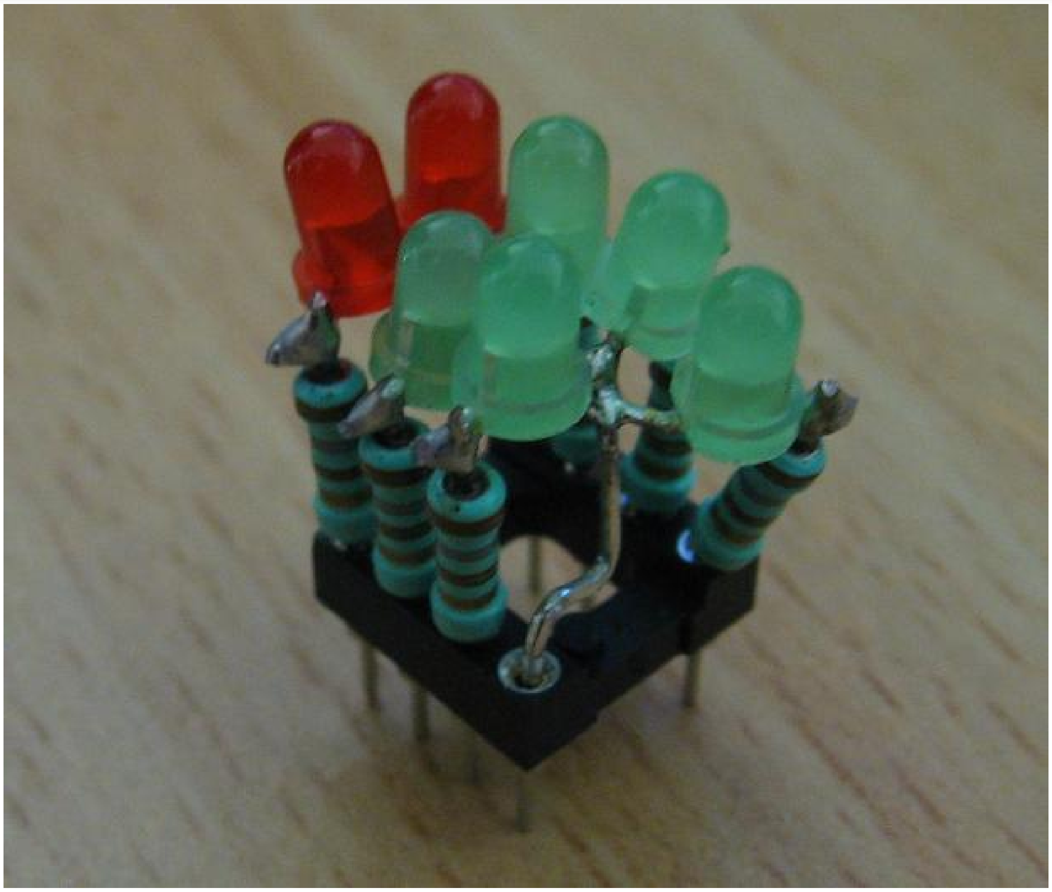
I was too lazy to make the trip downstairs to get my Win32 laptop and look at the waveforms using my USB DSO, even when I eventually strongly suspected this was the cause. My laziness probably cost me hours of frustration, but I blindly added an RC low-pass in the clock line and everything started magically working. Don't you just hate that! Especially after you've spent most of the day wondering if the datasheet is wrong. (The ATtiny13 datasheet version I have actually does have several other errors I've noticed, but apart from a redundant address bit for reading the OSCCAL it appears the HVS protocol table is correct.)



Anyway, the programmer has some switching to control Vpp and Vcc via a few data pins on the PC parallel port, the rest of the signals are directly bit banged, with the exception of the SDO pin, which has a pull-down for the initial HV-programming mode assertion. I depended upon the status line pull-up in the parallel port, supplying none externally.

Adventures also included smoking a 2N7000 accidentally when I shorted out the drain resistor with the multimeter probe and the PNP above it delivered the full current the PSU's 4000 uF of storage at 15 volts could deliver through the EB diode drop. The 2N3906 was unharmed surprisingly, but the 2N7000 explosion was quite spectacular. Naturally this didn't help my frustration level with the project! I was almost about to give up and just dig another ATtiny13 out of the rail from Futurlec when that happened.

Some moments of desperation caused me to build a LED on 8-pin IC socket jig to physically watch the logic levels change at a very slowed down rate and verify my code wasn't completely wrong:



The code is very basic, it just reads all the fuses out of the device and then blindly does a chip erase and sets the fuses back to the factory default. It expects to be run in Linux with /dev/parport0 being the interface to use. Calling it "rescue-attiny13.c" might be more appropriate than "hv-programmer.c". In the end it worked nicely and unbricked my device - I was happy.

I should probably build this as a permanent circuit and finish the code, adding argument parsing and other niceties. I don't think I'll bother implementing flash/eeprom read/write, once you've fixed the fuses you can use SPI to do that. You can always use this programmer just to un-bugger a device you've bricked.

3 comments.

Attachments

title	type	size
The Circuit Diagram	image/jpeg	64.603 kbytes

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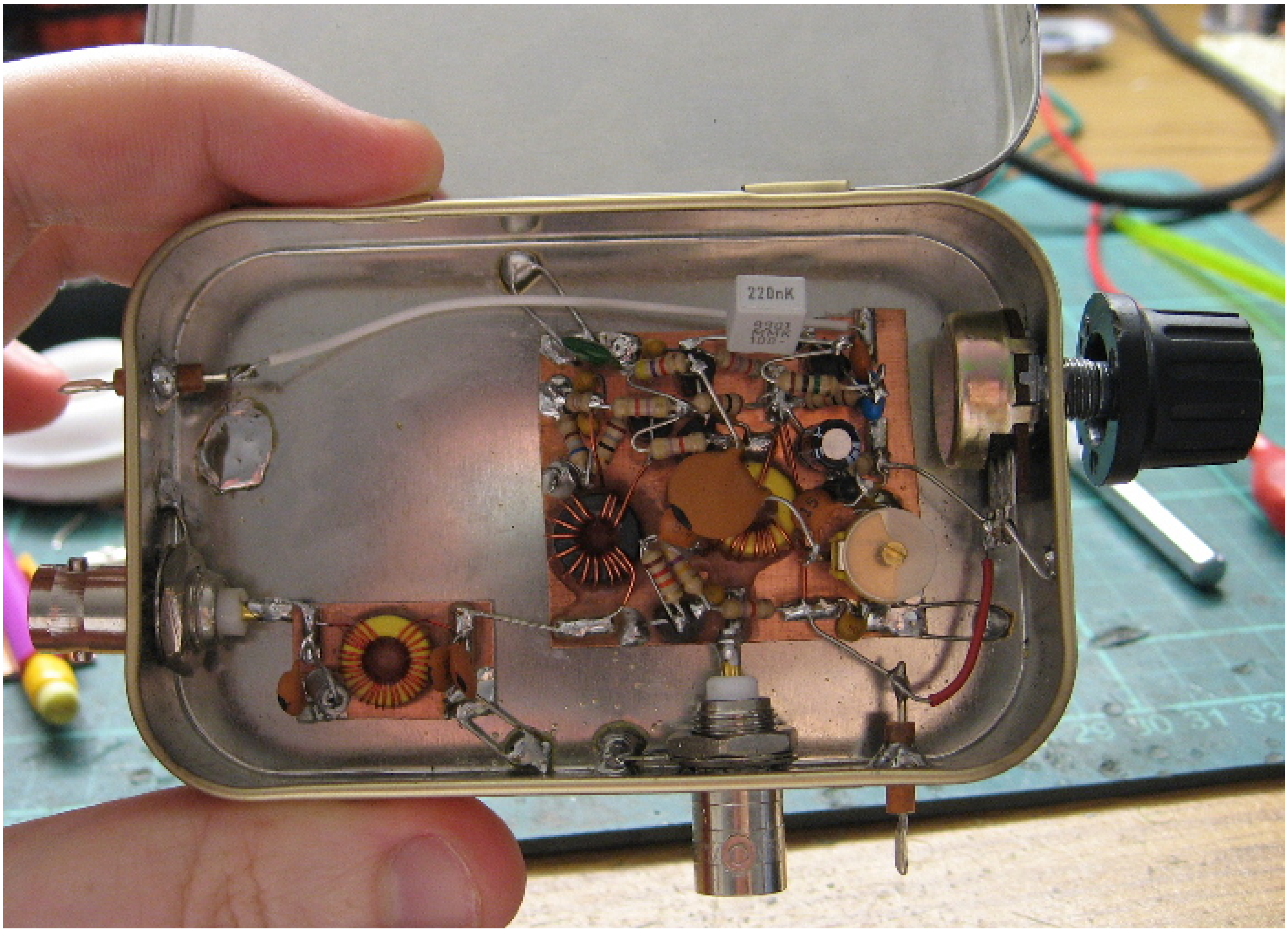
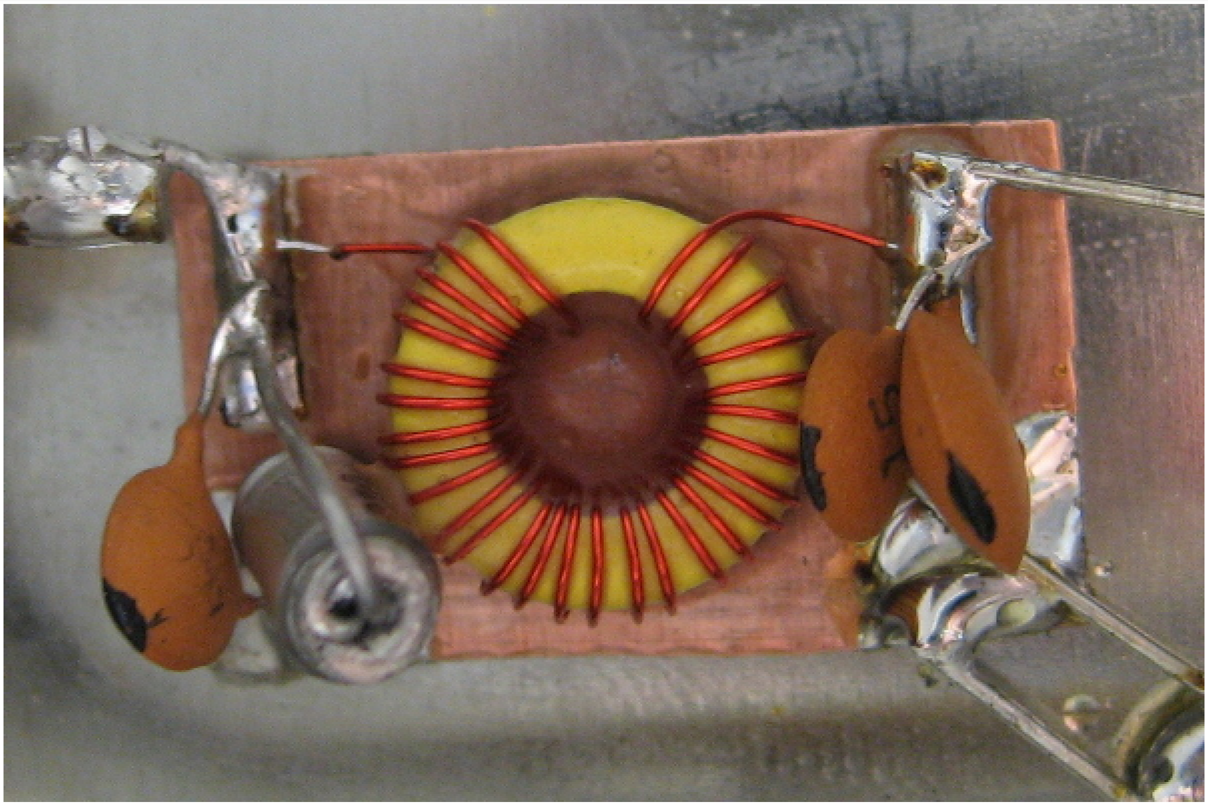
Autodyne Receiver Now In a Box

2008-02-04

I've whacked the 30 Metre Autodyne Receiver into the an Altoids tin along with a front-end low-pass filter and impedance matching network.



The input impedance magnitude was measured to be approximately 820 Ohms, dropping slowly with increasing frequency suggesting a somewhat capacitive reactance as well. A low-pass Pi matching network was computed to transform this to a standard 50 Ohms. The filter was built on a small piece of circuit board, 2.5 uH implemented as 29 turns on a T37-6 core, the shunt capacitances as a mixture of NP0 ceramic and Polystyrene capacitors. The input capacitance was absorbed into the high-side shunt capacitance, although its magnitude is quite small and the moderate design Q of only 6 means it wasn't especially critical to do this.



The filter was tested after construction with a hacked together return-loss bridge. Matching my signal generator into an 820 Ohm resistor it showed better than 0.5 Γ over about 2 MHz centred around 10.2 MHz. This is quite consistent with the design, and the precision of the measurements which wasn't very high. Similar results were seen into the receiver front-end once installed - actually I accidentally installed the filter backwards at first, additional testing of the input return loss showed my error quite quickly. (The receiver also performed extremely poorly with the filter reversed which was a big hint - it was quite deaf and had troubles locking even strong signals.)

The Antenna input and RF output are made via BNC connectors. The DC power and AF output pass through feed-through capacitors. The shielding with the lid closed is quite good, completely eliminating any tunable-hum and the VHF interference problems. The low-pass input, while not very aggressive is quite sufficient for my purposes. You can try a two or three resonator band-pass if you experience persistent problems.

There is sufficient room inside for an AF amplifier and even a small mylar speaker in the lid of the tin. This would make the receiver self-contained (except for the PSU of course).

1 comment.

Parent article: 30 Metre Autodyne Receiver.

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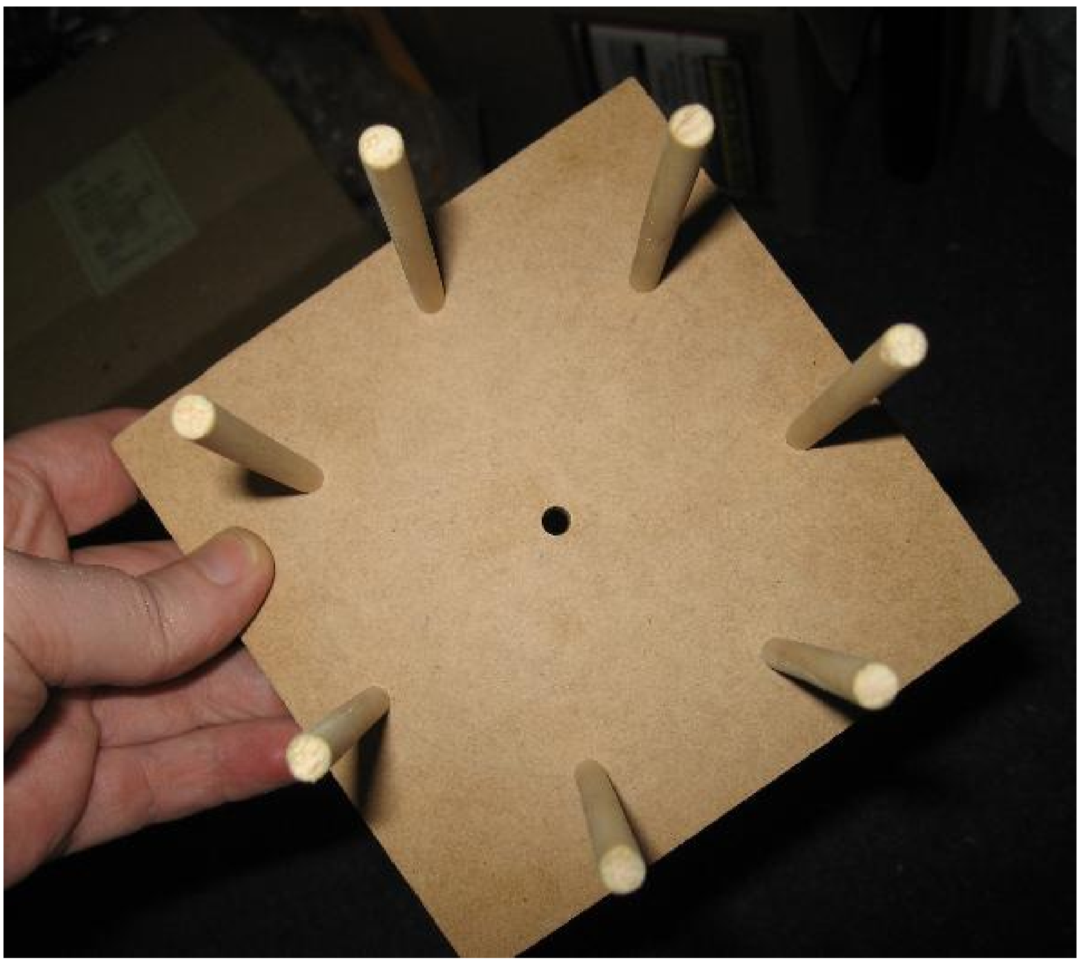
Basket-Weave Coil Jig

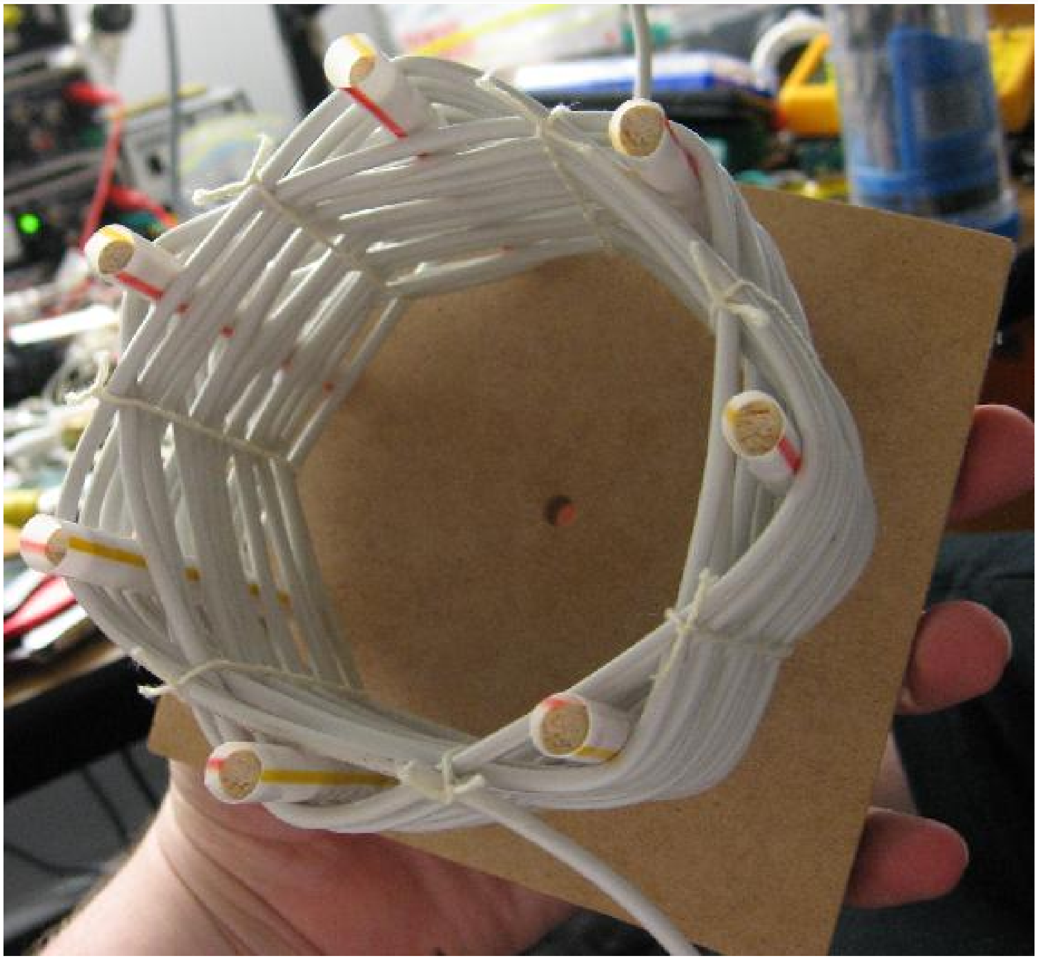
2008-10-25

A mate in Queensland was discussing building a crystal set with his daughter to help introduce her to homebrew electronics. The discussion kicked off some thoughts and eventually modelling of crystal sets with Spice... The Q of the resonator being the major figure of merit I wanted to attack first, research into high-Q coils at MF brought up the old spider web and basket weave geometries to decrease distributed capacitance and the proximity effect. I had to try this in practice and see just how much of a difference it made.

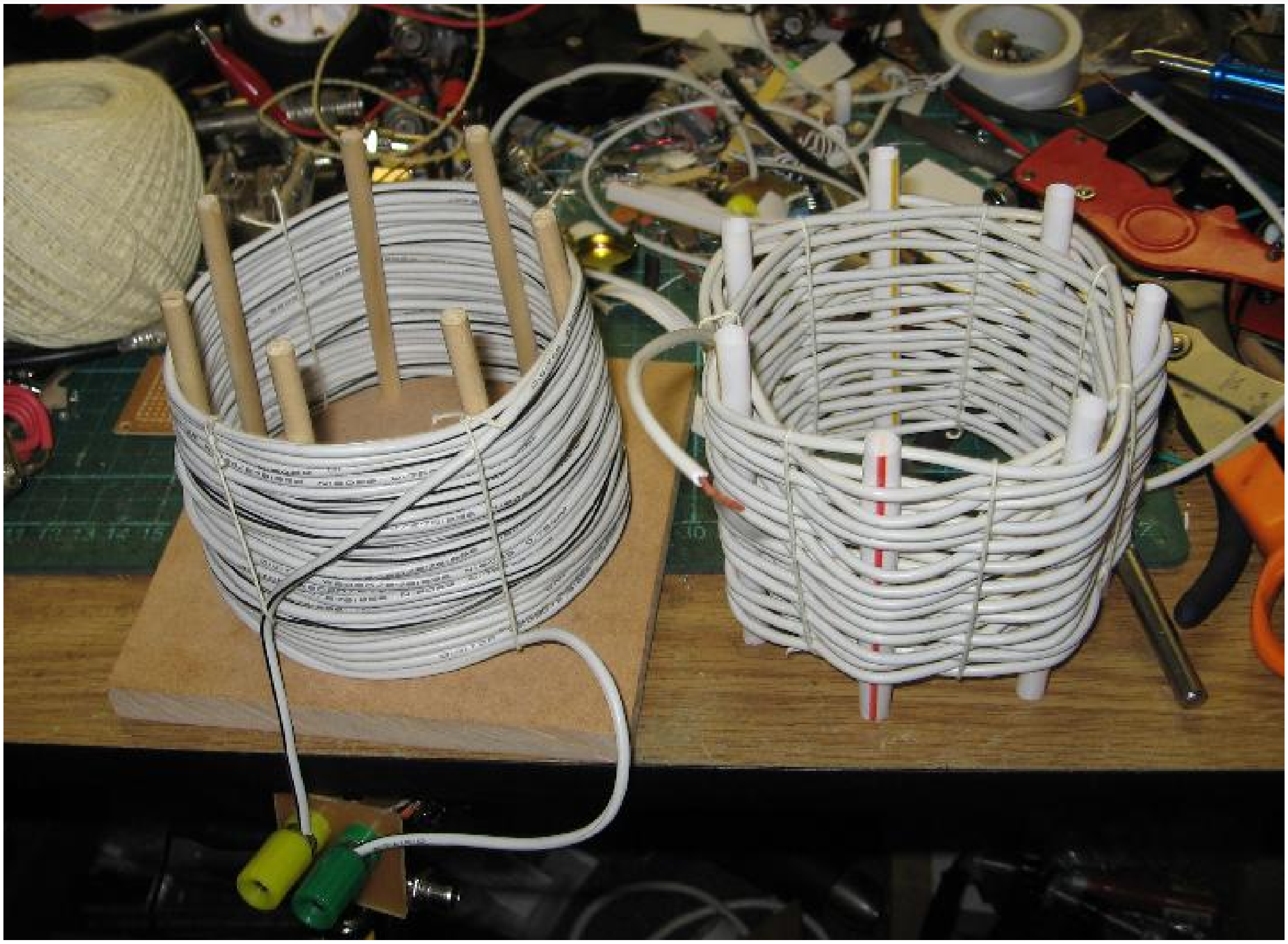
To this end I built a quick jig for winding basket weave coils. The base is just a 5" square piece of MDF. I wrote a calculator to help construct the dowel spacings around the 100 mm diameter circle. This particular jig has just 7 pins (it must be an odd number), each 6 mm in diameter, which is a good fit to common soda straws - helpful for keeping the coil in shape after it has been removed from the jig.



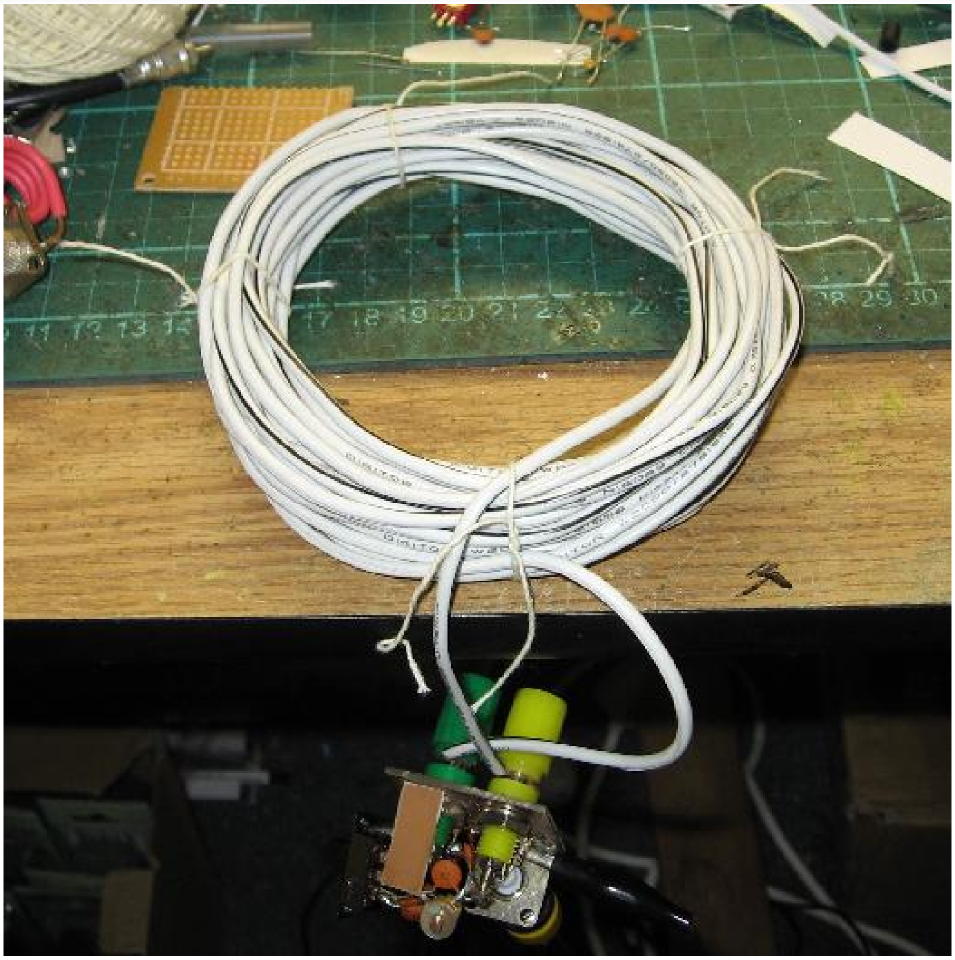
The first coil was wound with 1 mm diameter multi-strand zip-cord from the junkbox. A length of about 8.5 metres, initially used as part of an antenna, it had been corroded at the ends and replaced. 27 turns were made with the available length, tied together with some cotton string. The inductance was measured at 55.8 uH with a distributed capacitance of 4.3 pF. Q at 2 MHz was 149 and at 1 MHz was 151. Not very good but considering the wire used this is to be expected.



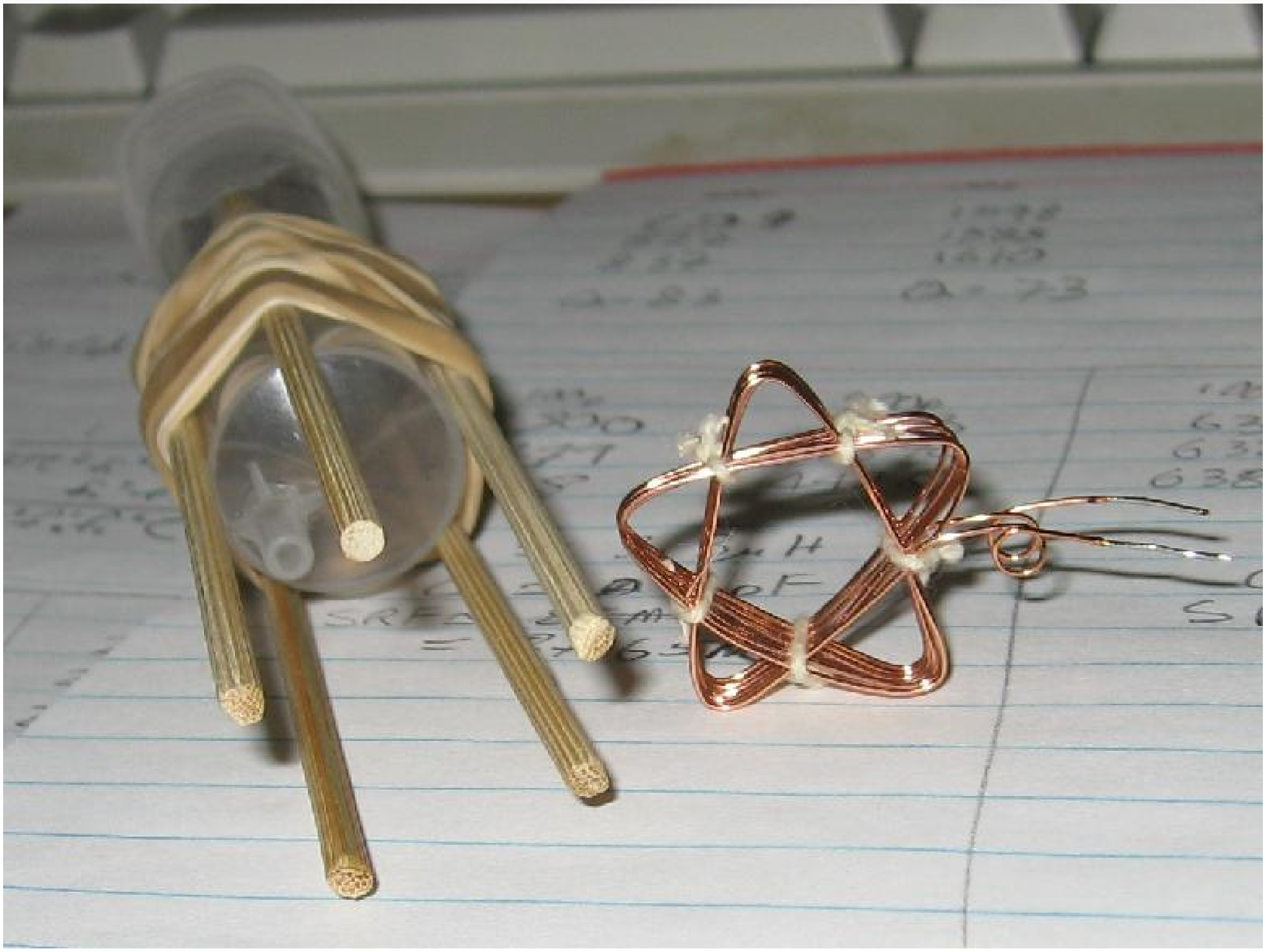
For comparison the other half of the same dipole was wound over the outside of the jig pins, giving an inductance of 62.1 uH and a distributed capacitance of 4.1 pF. The Qs where 165 at 2 MHz and 167 and 1 MHz. That didn't seem right at all, better Q and lower distributed capacitance. I'd clearly not taken enough care with the measurements or the corrosion of the wires had migrated unevenly and further into the cable than I had discarded.



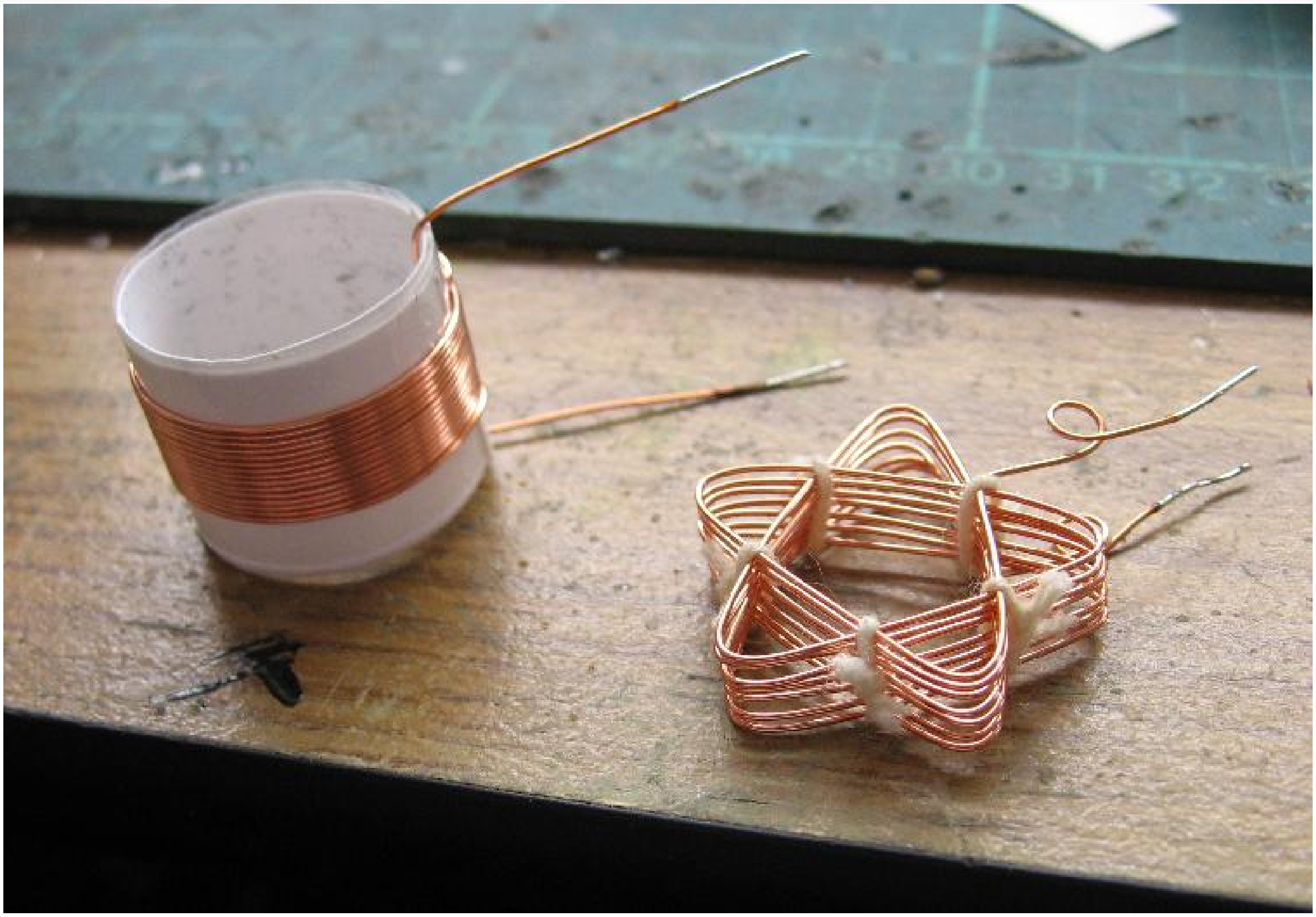
To make sure I wasn't going insane I bunched up the "close wound" coil into a doughnut-shaped bundle and repeated the measurements. L = 88.6 uH, Cd = 11.9 pF, Q = 83 @ 830 kHz, 73 @ 1.6 MHz. That looked better, and got "worse" as I tightened up the bundle by tying more strings around it. Still it didn't leave me feeling very confident that my choice of the junk-box zip-cord wire was representative. I initially thought it was the worst choice and would make an interesting lower bound - that it did, but its properties also probably hid any real advantage of the basket weave. Its jacketing definitely makes a coil much longer for the same inductance because it effectively spaces it out for you. The dielectric properties of the jacket are also an unknown.



Frustrated by this likely invalid result I decided to go smaller. A 5 pin basket weave jig was constructed using BBQ kebab skewers and a 25 ml syringe barrel (about 20 mm in diameter). Using this jig and 0.5 mm enamelled copper wire a quite artistic pentogram-like coil was wound, giving 3.3 uH of inductance. My initial resonance measurements had sufficient error to cause -ve distributed capacitance results in my calculator - however it gave an accurate estimate of the true inductance and placed the distributed capacitance in the 0.5 - 1 pF region. The Q at 8.8 MHz was 176 and at 4.4 MHz 96. Self-resonance was measured using my tone dipper and the frequency measured to better than 1% by comparison against the signal generator and counter; 87.7 MHz which put the distributed capacitance at almost exactly 1 pF.



For comparison purposes a close-wound solenoidal coil was constructed of similar diameter and turn count using the same 0.5 mm wire. I was shooting of the same inductance, but overshot by almost twice at 6.3 uH. I guess leakage from the very non-circular cross-section of the basket weave coil is significant - the value estimated by the coil calculator is close to that for the solenoidal coil, but even reduction based on the approximate cross-sectional area still over-estimates the inductance a bit. I guess it is a bit like having two mutually coupled coils of triangular cross-section in series with the turns interleaved out of alignment. The solenoidal coil distributed capacitance was also lost in the initial resonance measurement error (considering the test fixture used is based on 100 pF and 400 pF caps trimmed to 1% and the distributed capacitance is about 1% of the smaller one this is not surprising! I'm lucky to measure anything except frequency to within 1%.). Self-resonance was measured in the same manner as for the basket coil and at 57.6 MHz gives a distributed capacitance of about 1.2 pF. The Q at 6.3 MHz was 114 and at 3.2 MHz 85.5.



Also for comparison purposed a "long-thin" solenoid was wound on a 8 mm soda straw with 0.5 mm wire. Also shooting for about the same inductance I got 7 uH and didn't bother to remove turns to bring it back to ~ 6.3 uH. Its Qs were 63 at 3 MHz and 91 at 6 MHz. Not very impressive and worse than both previous coils on a root-frequency basis. The SRF was 78.3 MHz, quite impressive for a 7 uH inductor, which is about 580 fF of distributed capacitance! Around half that of the basket-weave coil and twice the inductance. This follows conventional wisdom that "flat" coils have more capacitance and a lower SRF than long thin ones, which in turn tend to make better chokes.

It is interesting to note that the slope of the Q change with root-frequency is much shallower for the basket-weave coil, suggesting perhaps its proximity losses are smaller. Only 2 data points for each coil is insufficient to say this, but it seems like the proximity effect reduction is visible in the numbers. More data points for each coil and comparison with a space-wound solenoidal coil would be a worth-while investigation. Measuring Q is laborious with the current jig and manual data reduction (3 dB points method - although I have recently constructed a 3 dB switched attenuator to make the process slightly more pleasant). A direct-reading Q meter would speed things enormously and will likely feature shortly.

The wire used in the larger coil is probably the reason the measurements were odd, in a way it is already spaced - by its jacket. Results with the smaller coils do look interesting. Once I have Q-measurement worked out I'll revisit this, and try using better wire, including some Litz wire I have (unfortunately not especially high-count). Litz wire could be homebrewed, but the machine to do it would be quite non-trivial, I could imagine doing it in hexagon-number (ie 7) wires at a time, then spinning 7 bundles of 7 together, etc. I think tension control would be the hard part, otherwise I'd invest in a few kg of very fine wire and give it a go - Litz wire is insanely expensive online and I haven't found an Australian supplier of it yet.

11 comments.

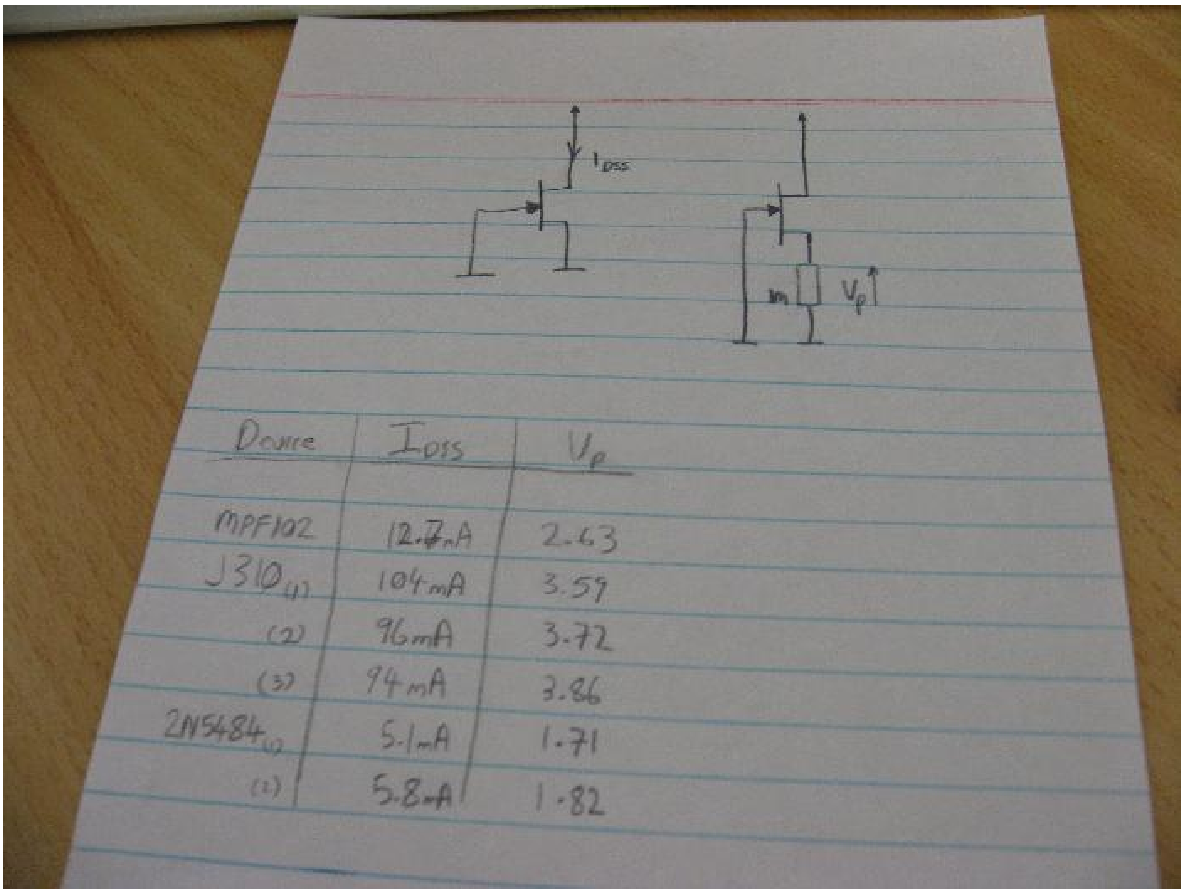
Biasing JFETs, AGC IF and other fun

2007-06-09

The W7ZOI tutorial on JFET biasing is a great place to start if you are looking to understand JFETs and use them in practical circuits. I encourage you to buy Experimental Methods, but the JFET biasing sidebar is reproduced on the popcorn site while you wait for the book to ship from the ARRL.

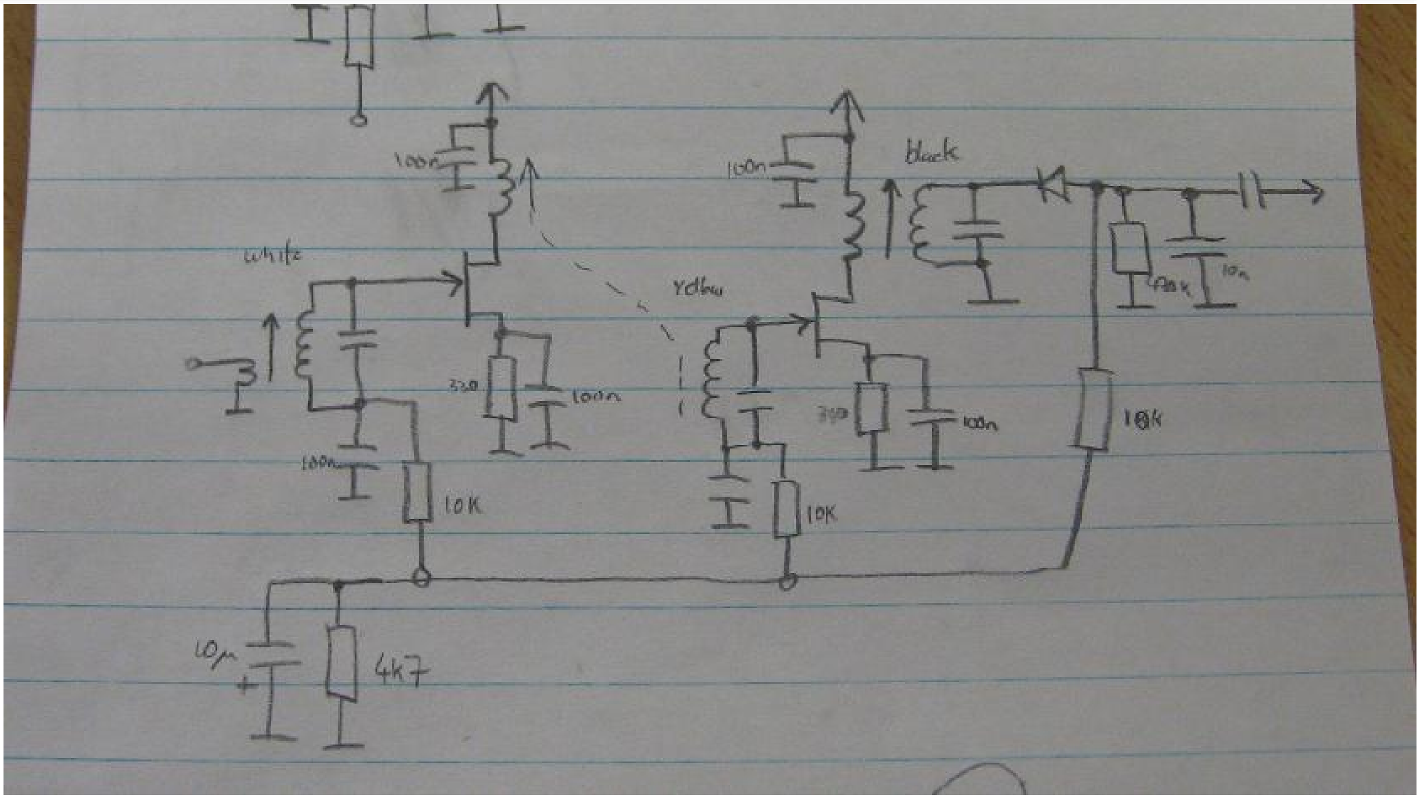
I wrote a simple calculator that implements this source resistor self-biasing. All you need do is measure your JFETs Idss and Vp then plug in the numbers to the calculator which will then spit out the source resistor required and the transconductance of the FET when biased like this.

I characterised three different JFETs from my collection, the MPF102, the J310 and the 2N5484. The J310s I tested gave an Idss of around 100 mA! This is far outside their datasheet spread of 24-60 mA, so I repeated the measurement several times on three randomly selected devices and played with biasing in trial circuits. The math was consistent, which makes me wonder about my particular batch of J310s. The J310 is obsolete, so perhaps these aren't NOS, but rebadged modern devices. I got them off eBay from a seller I trust. I guess the higher saturation current is actually a blessing, making them more useful at higher powers.

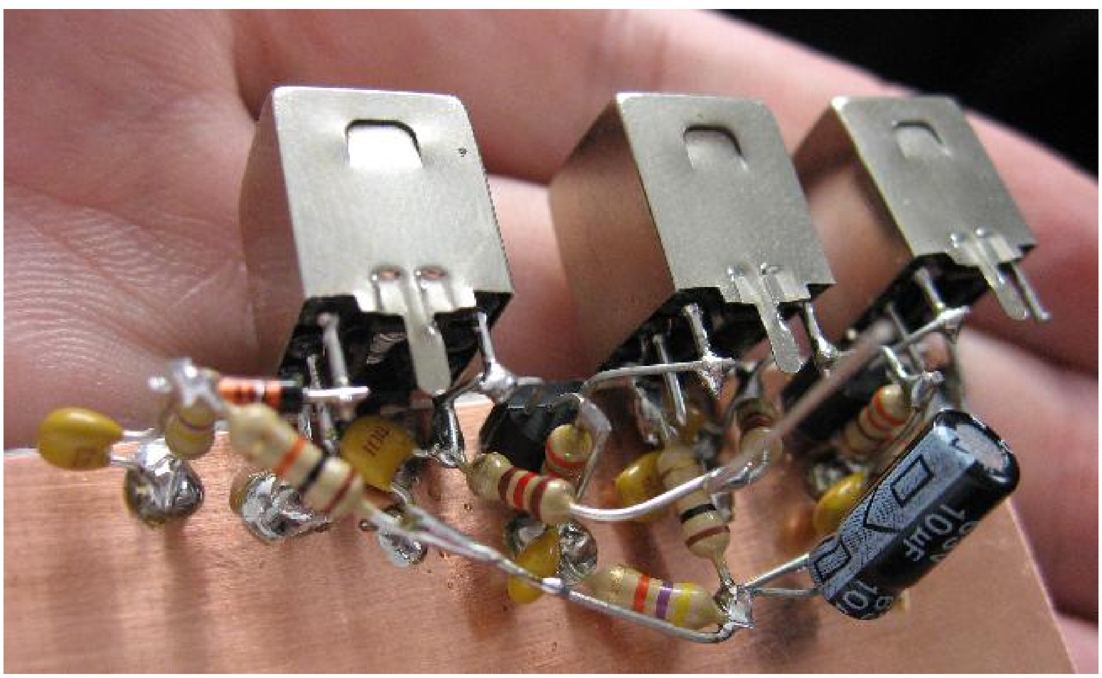


I selected 2N5484 for my AGC IF experiments, its lower Vp sounded easier to generate with a single diode detector, but this and their relatively low transconductance would limit the AGC range achievable. I picked an Id around 2 mA for the quiescent bias which is achieved with an Rs of 330 Ohms.

A very straight-forward JFET IF circuit was constructed, using a set of 455 kHz IF cans, the line-up being white into the 1st FET gate, yellow in its drain and the 2nd FETs gate, and black in the 2nd FETs drain feeding the detector. The untuned sides were placed in the drains, this was against my initial instinct, especially for the detector, but it seems to work fine. The IF cans themselves are designed for lower impedance BJT devices, so the design is sub-optimal, but it offers a reasonable 40 dB or so of dynamic range.



The AGC voltage is applied to the decoupled cold-side of the gate resonators. The AGC time constant is quite short, but I prefer it that way. Without AGC the circuit is actually slightly unstable, with at least 33 Ohms needed in the drain circuit of the second stage for stability, but once the AGC rail is unshorted it floats about -0.12 volts and the IF amplifier works great. The AGC rail swings down to about -1.8 volts before the dynamic range of the amplifier is exceeded and gain compression begins at the second stage, the distortion becoming severe by 2 volts below ground.



The remaining red oscillator IFT could be used to build an autodyne converter for a front end, completing a MW receiver with only two more active devices (one for the AF-side as well). However, this IF stage might find use in the 80 Meter Challenge receiver, if I ever finish that!

7 comments.

Bicycle Rim Antenna for 20 Metres

2008-03-08

Several months ago I was walking home from the post office, nearing my place I saw it was "clean-up week", the curb dotted with various piles of junk people had put out to be disposed off by the council pickup. The pile outside my block of units had mostly busted furniture, but one item caught my eye, an Aluminium bicycle rim. I dug it out and took a closer look. The spokes and hub were all rust-pitted chromed steel, and physically it was for a child's bike, only around 580 mm in diameter, but the Aluminium itself looked to be in good shape. Antenna was the immediate thought, so I carried it back to the shack.

The spokes and hub where removed and discarded. The rim had a join where steel pegs had been inserted into cylindrical openings in the extrusion and epoxy used to close and secure the join, forming the round shape. I used a cut-off wheel on the rotary tool to cut through the join, breaking the rim so I might measure and feed it.

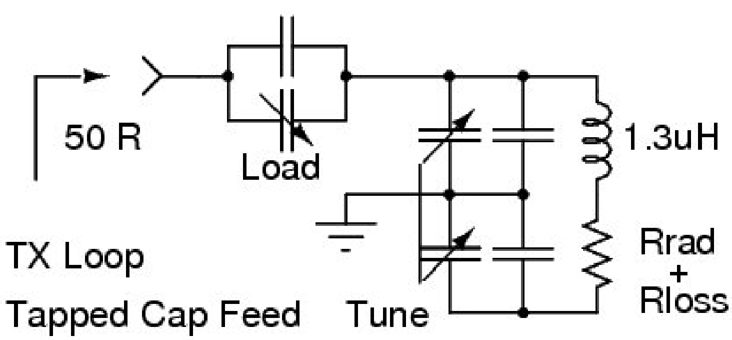
Experiments

The rim is roughly 1.3 uH of inductance. This is a good fit with the "ring" inductor formula. I experimented with the loop of metal for some months before I finally settled on making it into an antenna for 20 metres. The efficiency is fairly poor on 40 metres and even somewhat marginal on 20, but on the higher bands it is an exceptional antenna. I even tuned it up on 11 metre CB and listened around, hearing not much but some Asian fishermen and the usual braindead 27.355 MHz crowd. It is self-resonant near 6 metres (distributed capacitance about 8 pF) and is therefore limited to upper-HF, roughly 30-10 metres.

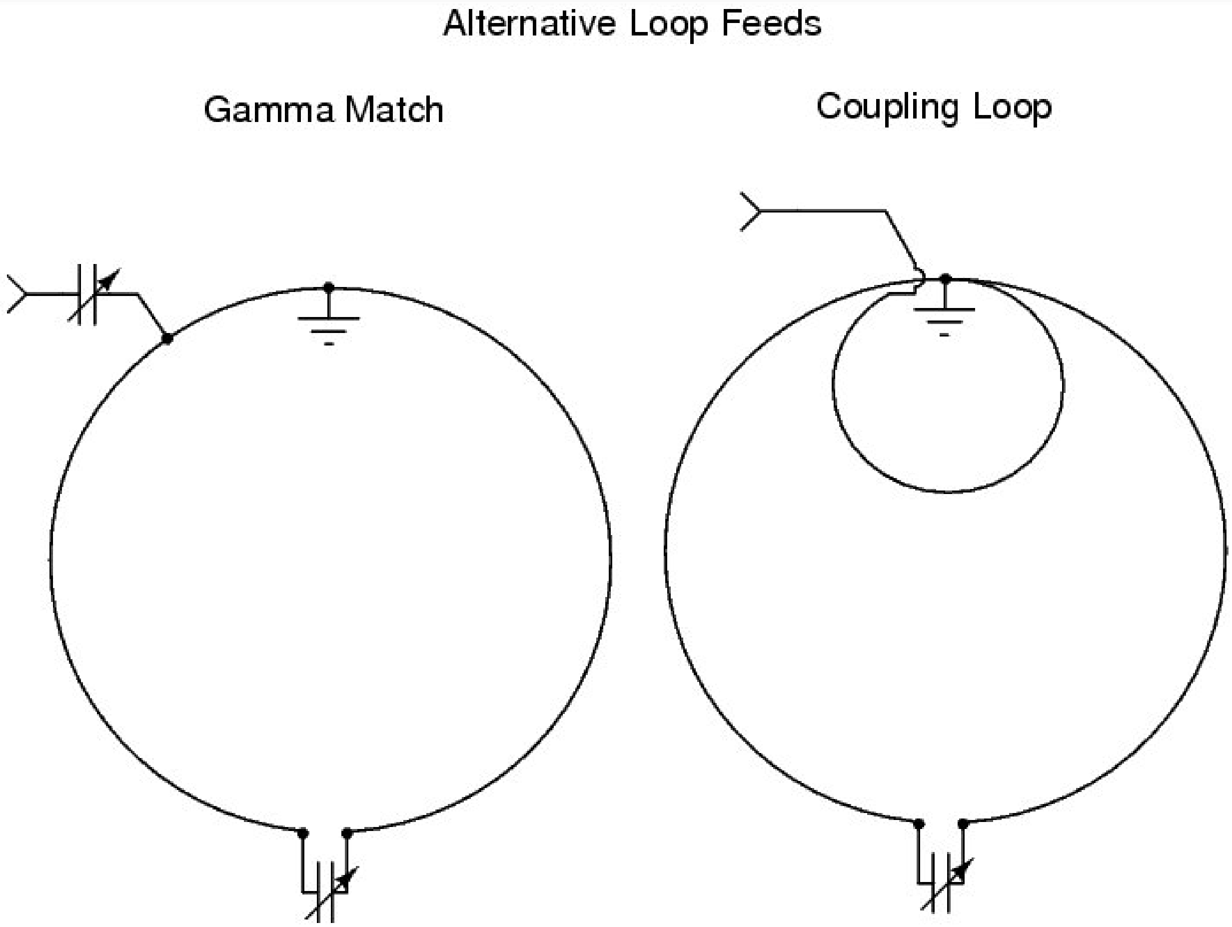
Loop Demo on 40 Metres
(7.930 Mbytes)

Radio Australia Demo
(4.982 Mbytes)

For its life on 20 metres I chose the more electrically straight forward and tunable taped-capacitance feeding arrangement. The disadvantage of this arrangement is that it is a bit more difficult to tune, as the match and tune capacitances affect each other, but some iteration finds a good match quite quickly.

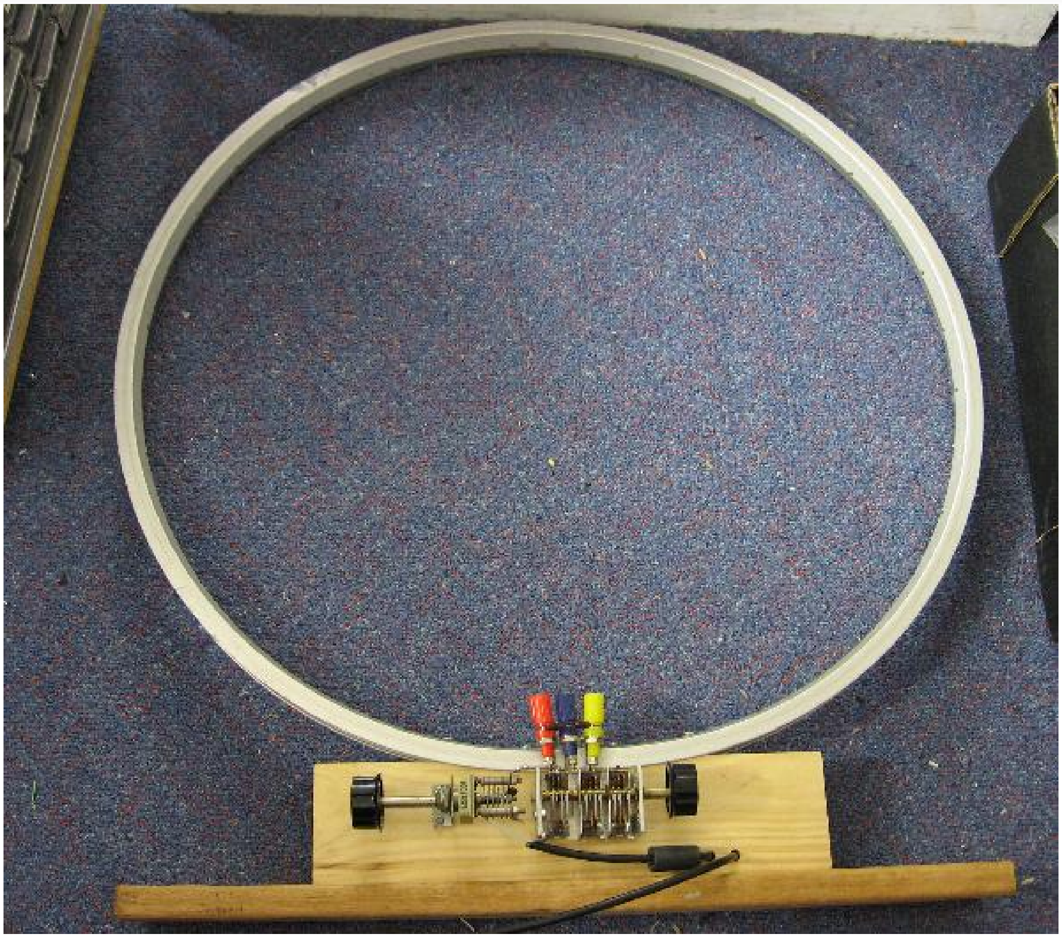


I did experiment with small coupling loop and gamma matching. Both work just fine but are a bit fiddly if you want to change bands a lot. Small driven loop has the advantage that you can twist the coupling loop with respect to the resonated loop to adjust the matching, and can pass the coax feed right through the main loop at its nodal-point where it has a voltage minima. The rim had a hole directly opposite the join where the tire valve likely was placed, this allowed hanging the loop by its coaxial feed. While interesting experiments and valuable lessons for future experiments, I like the tune/match capacitor coupling I ended up with.



Construction

The loop was screwed to a piece of timber (a poor insulator unfortunately) as a base. The tuning and matching capacitors were screwed to the timber base as well and the coaxial feed fed though some holes in the timber as strain relief. The tuning gang was used in "split-stator" mode to reduce losses, leaving it with a capacitance range of about 20 pF. Some binding posts were used to allow different silver-mica transmitting capacitors to be put across the loop to shift bands.



Two 160 pF capacitors are used for 20 metres, giving an equivalent capacitance of 80 pF. The loop tunes about 13.9 to 14.6 MHz, and the 2:1 VSWR bandwidth exceeds this.

The matching capacitor is a fixed 18 pF in parallel with a 10 pF trimmer. This value was determined experimentally with a signal generator, mini C-jig, and return loss bridge as the best arrangement for matching the loop over the frequency range of interest without excessive touchiness in the tuning.

Notes

Power handling is limited by the capacitors. The Silver-Mica caps used are rated to only 200 Volts, but for my current QRP use this isn't a problem. Efficiency if affected a little bit by using binding posts instead of soldered connections for the capacitors as well. I'll probably solder the caps in place permanently once I settle on them, but I am hoping to find higher voltage ones on eBay first.

The connection to the Aluminium of the rim is made with nickel plated hardware, thick copper wire and lots of star washers, etc. Ideally it should be spot-welded, as should all the rotor plates in the capacitor to the shaft and the stator to their connections. The stator plates are copper, I've never seen a capacitor quite like this one before, it would be possible to solder them together to reduce the losses. The rotor plates are Aluminium, the shaft brass, which presents more of a problem. The shaft has an inbuilt coaxial reduction drive with a 1/8" shaft that comes out of the middle of the 1/4" one. I'm having problems finding a suitable knob.

A ferrite suppression bead was slipped over the coax feedline near the feed-point to reduce a slight interaction with the coax position/body capacitance upon return-loss seen while experimenting.

9 comments.

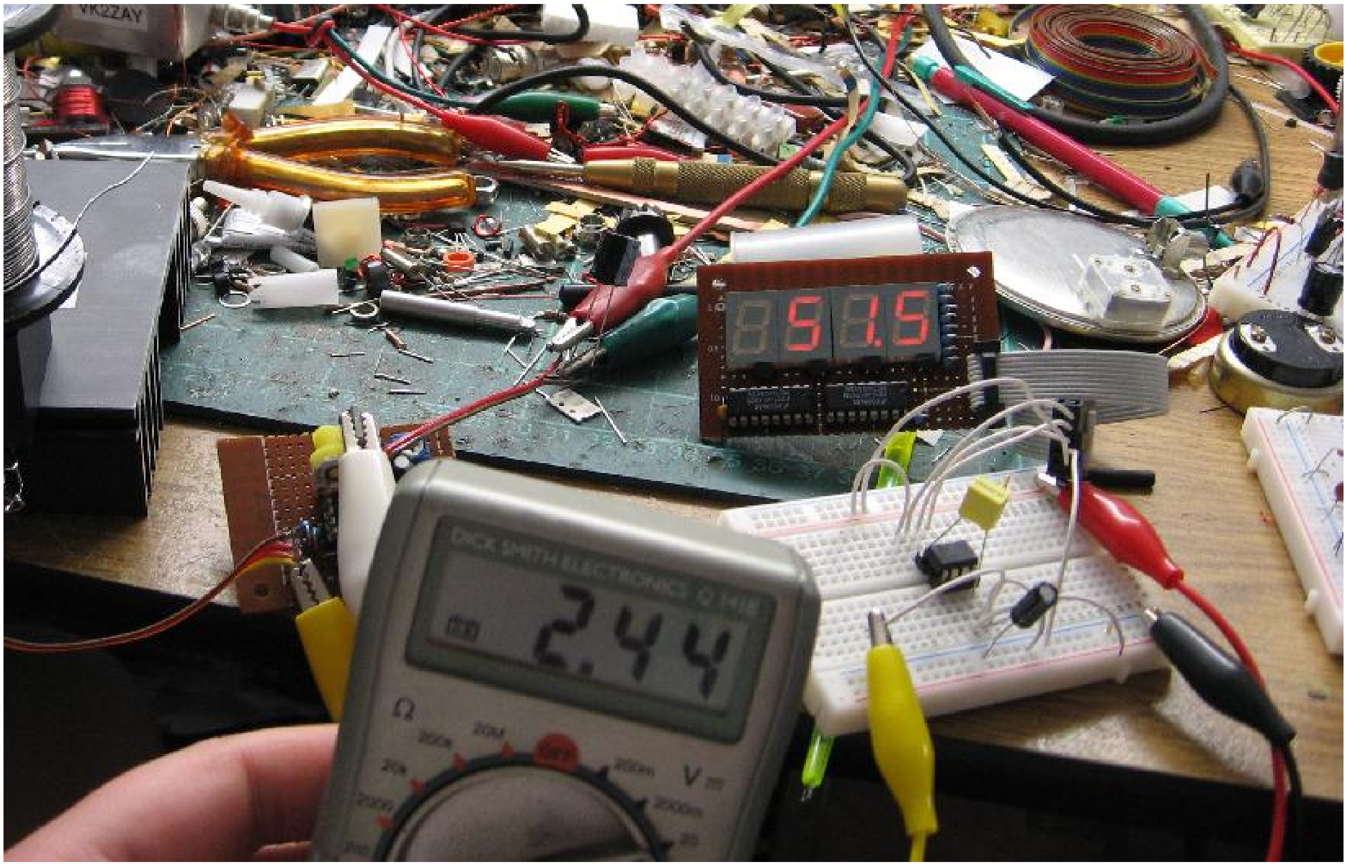
Attachments

title	type	size
Feed Network Diagram Source	application/postscript	11.601 kbytes
Alternative Feeds Source	application/postscript	10.002 kbytes

Digital Display for the Bolometer

2009-03-01

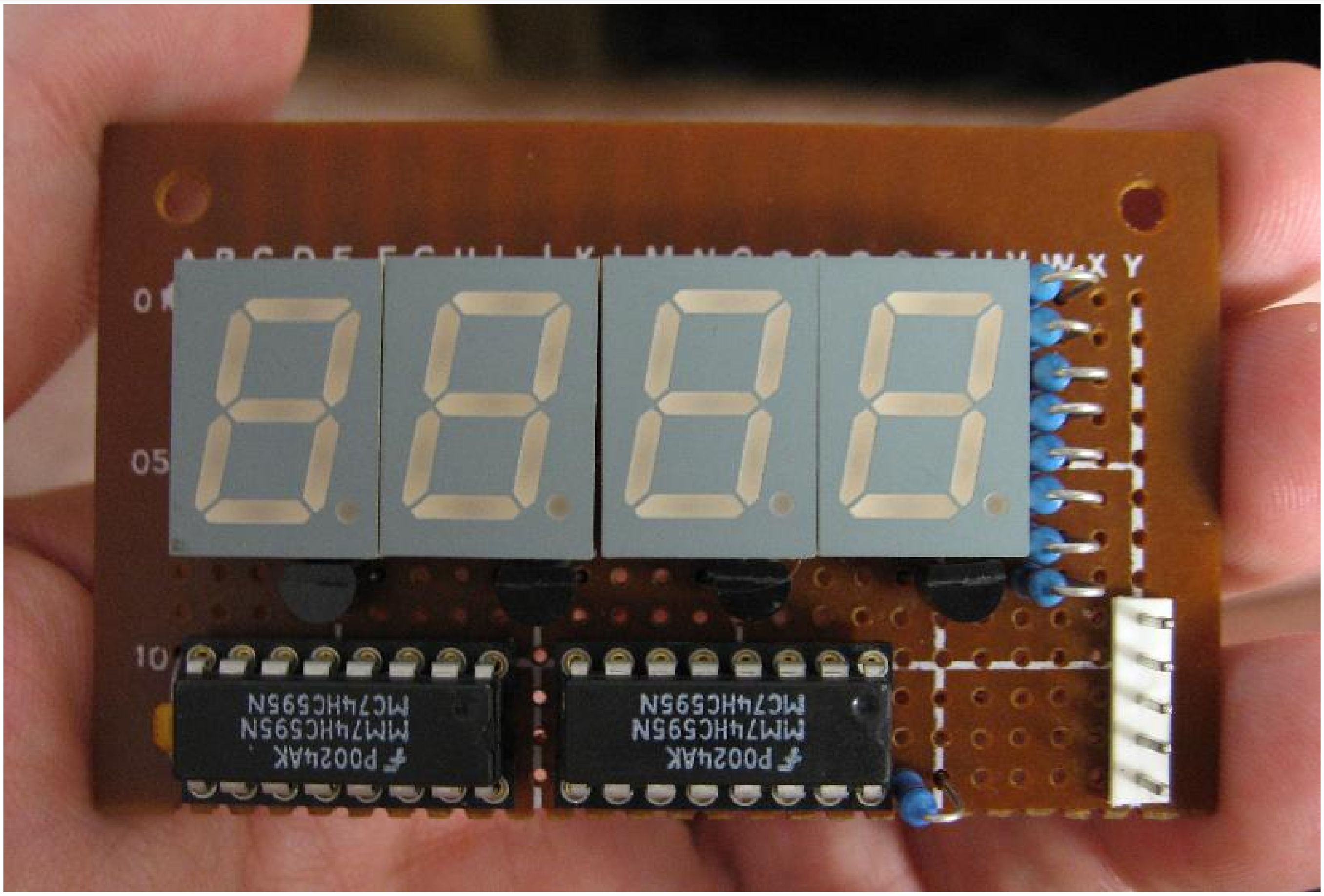
To make the bolometer direct-reading I threw together this relatively simple 4-digit 7-segment digital display, driven by an atmel ATtiny13V. The tiny13 ADC measures the heater supply voltage, and computes the current applied power based on its memory of the quiescent bias power. The bias zeroing power is remembered with a button press.



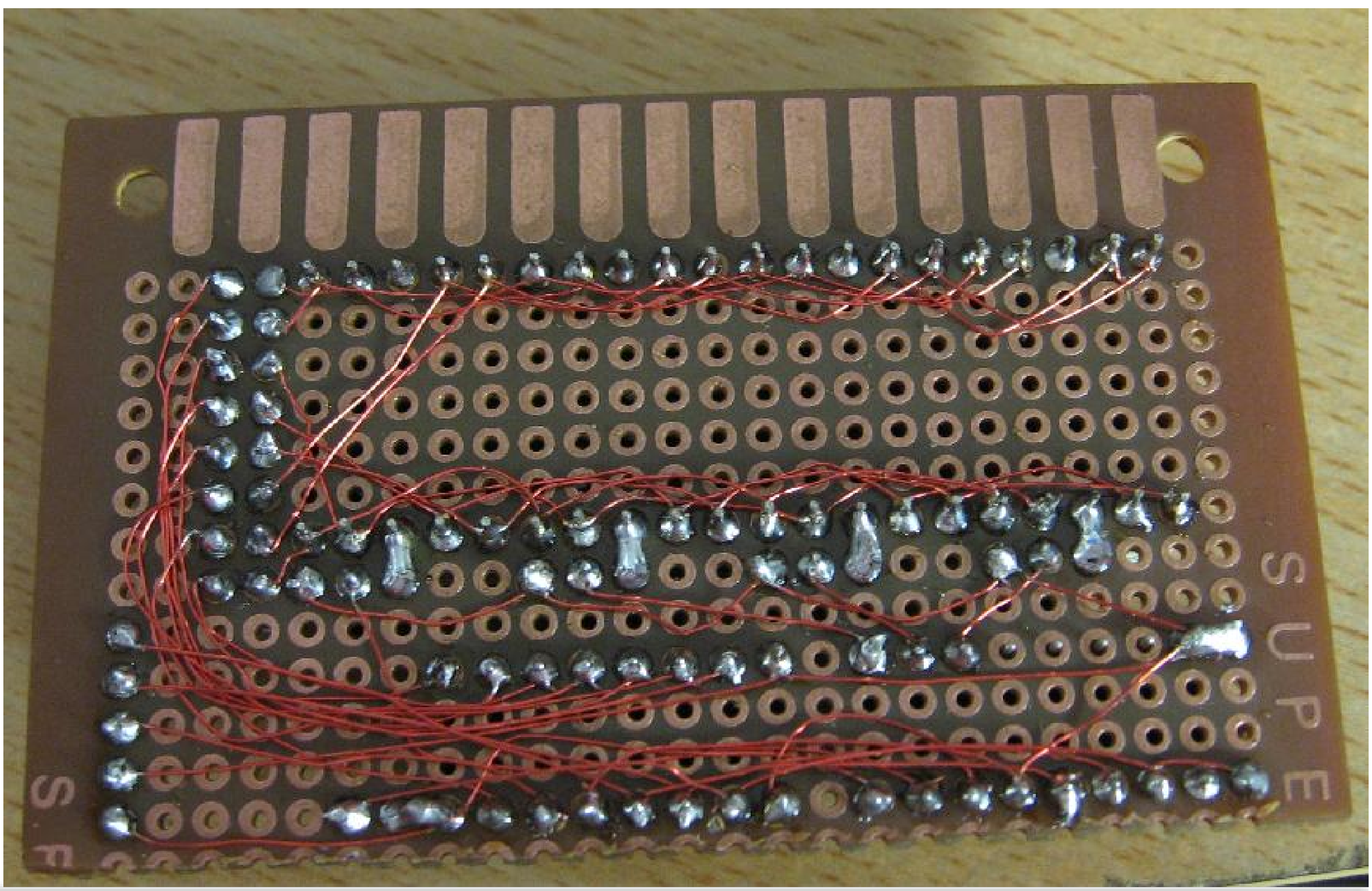
Hardware

The display is quite straight forward, but a little involved to construct because of the low IO pin count of the ATtiny13. I did not have an LCD display in the junkbox, but I had lots of 7-segment LED units, so naturally enough I used what I had. A pair of 74HC595 serial-in parallel-out registered shift registers does the 3-wire to 12-wire conversion required to multiplex the display. The displays are common cathode, the 8 anodes (7 segments + decimal point) are fed by the first 74HC595 in parallel through current limiting resistors. The four cathodes are each connected through a 2N7000 multiplexing FET, and the FET gates driven from the 4 LSB of the second 74HC595. (As there are 4 spare multiplexing pull-downs the general scheme could drive 8 digits).

I briefly toyed with using 4 74HC595s, one for each 7-segment unit so each would have its own 8-bit memory register... While this would have simplified the driving logic (no need to multiplex, just clock the data in once and latch it), it would have meant 32 current limiting resistors and I didn't feel like soldering in that many (also I lacked 32 220 ohm resistors anyway).



The wiring pencil once again made the construction fairly swift. The wiring is quite dense and much care was required, but otherwise construction was uneventful.

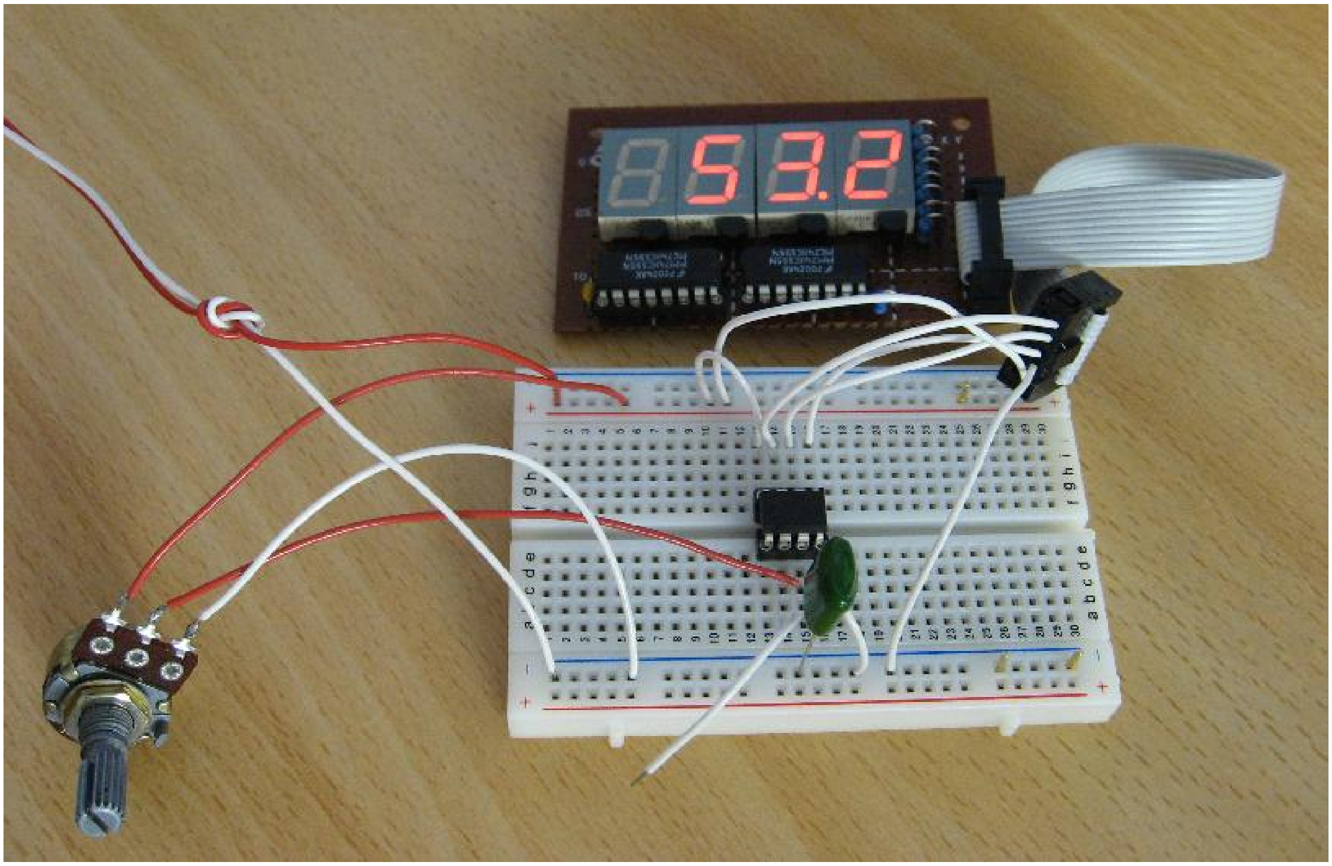


The display interface is via a 5-pin header. Two power lines, one data, and two clocks (shift and output latch). I toyed with the idea of bringing out the output enable so the display could be blanked and perhaps made somewhat more fail-safe in the event of lost multiplexing drive (which might cause excessive current in the static display). Instead I just used 220 ohm dropper resistors, giving a somewhat dimmer display but an inherently fail-safe one. The reset line of the tiny13 would be required to drive the enable line anyway as I needed two spare pins for the rest of the application.

Software

The remaining work is simply software. The display is multiplexed continously in a tight loop. The digits are bit-mapped into a byte wide, 18 byte long table for the digits 0-9, A-F, decimal point and blank. (The last two being trivial and not strictly required). I tested the display by having it dump a 16 bit integer in hex that was being incremented... The final application only requires the 0-9 (and E) states, so the rest could be omitted to save ROM space. The current version of the application takes about 900+ bytes so it just fits.

The ADC runs continously in auto-triggered mode. This is a problem as the ADC noise is significant and the application really needs more than the 10 bits of precision available... I need to work on this some more. The tiny13 timer is being used to periodically update the display state vector. It is possible to use the timer interrupt to trigger an ADC conversion in full noise-reduction sleep, but it will cause a small gap in the multiplexing which may be noticeable... Haven't tried that yet.



It does however basically work. The power computation is done in fixed-point arithmetic using longs. One intermediate code version was simply a 0-5 volt display (which worked quite well). A pin-change interrupt is utilised to cause memorisation of the current heater power (i.e. the zero button), each timer interrupt the difference between that value and the current value is placed into the display vector.

While annoying to wire-up the display is straight forward, easy to drive and expandable almost without limit. The dedicated register version would be quite nice as it requires no CPU time to maintain, you just clock in new data when you want an update. The 74HC595 can be clocked at 100 MHz, so most MCUs need no wait states and only a few cycles per segment. A PCB would remove the drudgery of building the display. The 74HC595 costs $0.30 - $1.50 depending on where you buy it, and 7-segement displays are about the same (4-digit display modules suitable for the multiplexing system I used are about $1.20 retail). At < $4 that is fairly competitive with LCD displays for a small number of digits. LCDs are obviously more flexible and cheaper but perhaps for some applications these nice bright displays are easy to build and talk to.

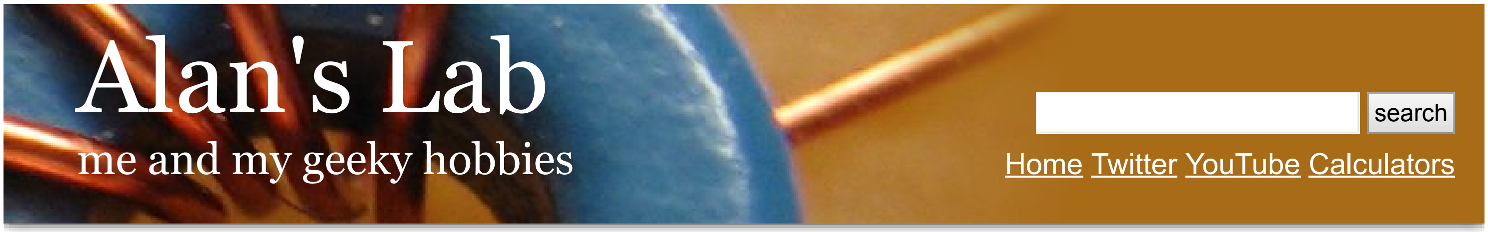
Application wise, the code is still work in progress. I think the limitations of the tiny13 will make the display stability an issue, the ADC just isn't good enough. Using a multimeter and a calculator is better for precision measurement, and the moving coil meter is nicer for general 1-100 mW trending. Building the display and its drive code was quite fun however, and probably more useful in the long run than a digital display for the bolometer.

Leave a comment on this article.

Attachments

title	type	size
The Code for the Bolometer Display	application/gzip	5.744 kbytes

Parent article: RF and Optical Bolometer.



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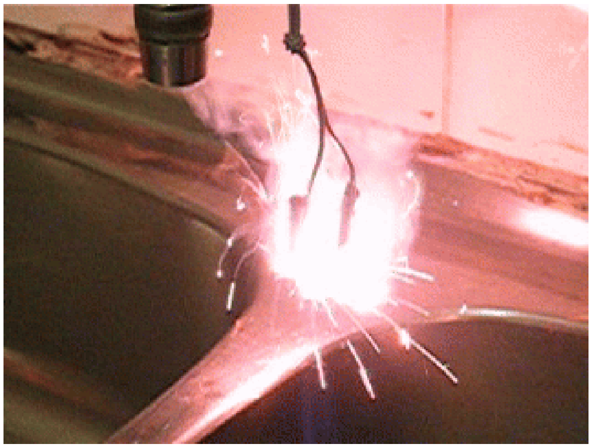
Electrical Ignition

2005-01-16

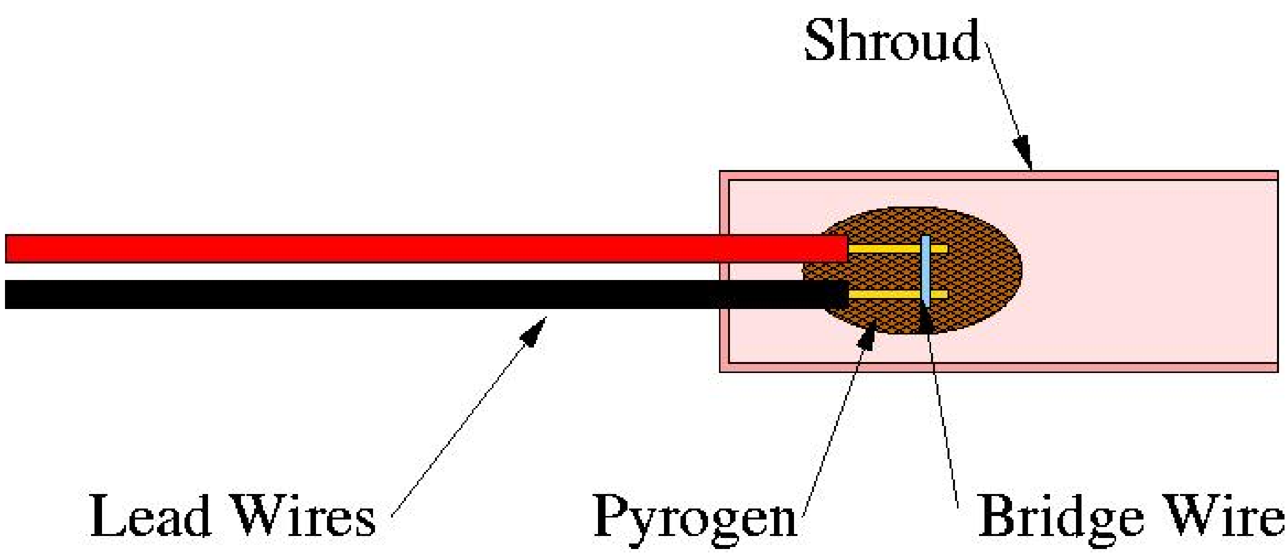


Theory

Electrical ignition systems use the ohmic heating caused by an electrical current passing through a conductor to initiate a pyrotechnic composition. They are typically designed to produce a short burst of hot gases and sparks for initiating other compositions further down the pyrotechnic chain.

Electric igniters, "fuse heads", "electric matches" or "e-matches", do not detonate. They contain only low-explosives and will not initiate a secondary high-explosive. However a similar device containing a primary high-explosive in a metal tube is called an electrical detonator and is used to initiate high-explosives. A "squib" is neither an e-match or electrical detonator, but is more similar to the later and must never be used to replace an e-match. The term "squib" is unfortunately ambiguous and is best avoided IMO. In this text we will address only e-matches used for igniting low-explosive pyrotechnic devices.

Physically e-matches are two wires that come together at the pyrotechnic end of the device where a small blob of "pyrogen" composition is found. Within this blob of composition is usually a very fine "bridge wire", typically of nichrome alloy, that connects each of the lead wires. It functions purely as a heating element, its job is to reach the initiation temperature of the pyrogen and reliably initiate it. Some e-matches, so called "bridgeless" e-matches, have no bridge wire at all, the pyrogen is formulated to be conductive and forms its own bridge wire. Some e-matches come with a removable plastic shroud that protects the match head and can be used to direct the gases and sparks if required.

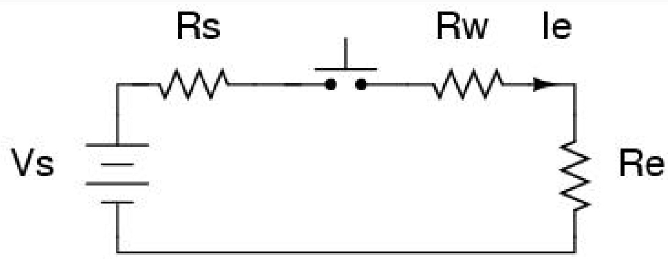


Electrically e-matches are essentially a pure resistive element. Typical values are 1.5 Ohms across the device. Commercial e-matches are rated by the "no-fire current" and the "all-fire current", the currents at which all units in a lot of devices won't "cook-off" and will reliably fire respectively. The no-fire current is typically 50 mA, and the all-fire current 500-1000 mA. The region between the all-fire and no-fire currents is undefined and must be avoided. The no-fire current is used for continuity test purposes in practical firing systems.

To reliably fire the e-match a voltage source is applied sufficient to cause at least the all-fire current to pass through the device for a specified time. Currents many times larger than the all-fire current still may not ignite the e-match if applied for very short intervals. Commercial e-matches come with a table or graph describing their "dynamic" behaviour with short-duration current pulses.

When computing the firing supply requirements it is important to take account of the line losses in the current loop between the supply and the e-match itself, as well as the internal resistance of the supply. The diagram and equation below can be used to calculate the minimum firing voltage given the supply internal resistance, the line resistance, the e-match resistance, and the all-fire current:

 XHTML | CSS | CSS toggle



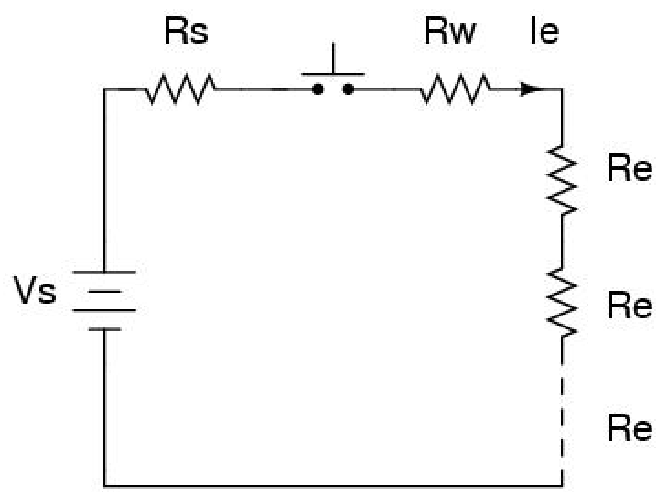
$$Vs > Ie * (Rs + Rw + Re)$$

As a simple example, take the supply internal resistance as 200 mR, the line resistance as 25 R, the match resistance as 1R5, and all-fire current as 500 mA. This results in a minimum firing voltage of 14.2 V. Ignoring the match and supply resistances would give you a figure of 12.5 V, which would not reliably ignite the e-match! In practical circuits the line resistance is typically the most dominant figure and adding "a couple of volts" over what is required by it will generally work, but be sure to do the calculation anyway.

Note that Rw figure includes ***all*** resistance from the battery terminals through to the binding post on the "slat" (or "rail") you are using, and the Re figure includes the resistance of the leader wires. Non-trivial resistances can accumulate, even with short lengths of hook-up wire inside slats and firing boxes.

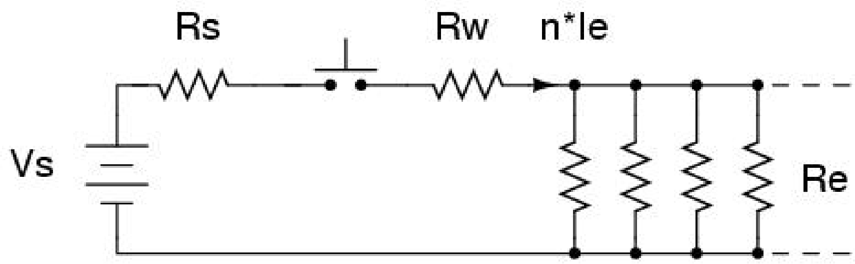
Multiple e-matches can be interconnected to initiate multiple devices at once. You have three choices in the connection topology; series, parallel, and series-parallel. Each has its own advantages and disadvantages:

Series connection is the most widely used in practice, it has the advantage of being easy to debug, as the continuity testing feature of most firing systems will detect an open joint. The individual e-match resistances accumulate slowly, requiring only an extra volt or so per additional e-match. However, as all the bridge wires are in series, should any of them open significantly before the others it is possible that not all e-matches in the loop will fire. Any significant difference in e-match resistances or pyrogen sensitivity can cause only a single match to fire, the most sensitive protecting the rest in the loop from the firing current.



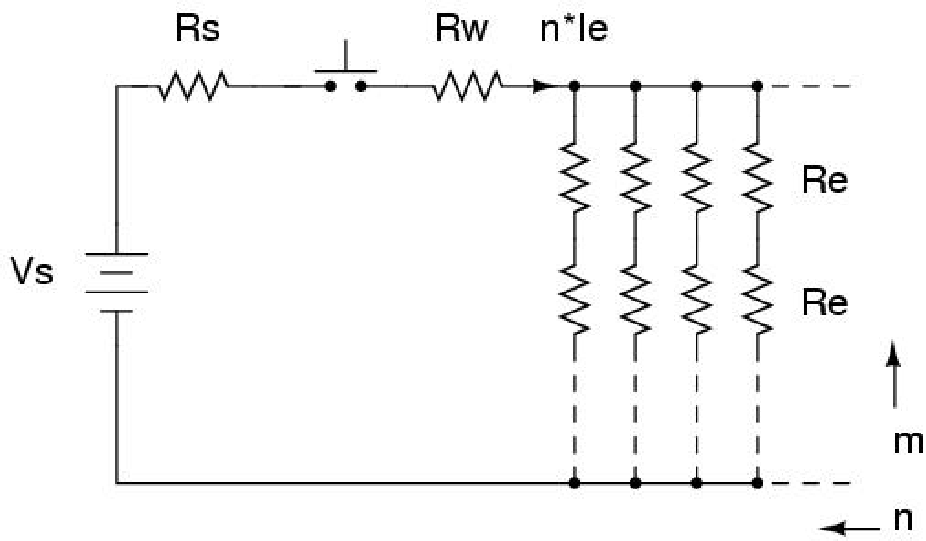
$$Vs > Ie * (Rs + Rw + (n*Re))$$

Parallel connection solves this problem, all connected e-matches will fire eventually. However as all e-matches are in parallel a faulty joint in the circuit can be be hidden by other correctly connected e-matches. Parallel circuits also demand larger current requirements from the supply and put limits on the line losses. For every N matches you have, Rs and Rw become N times more important:



$$Vs > (n*Ie) * (Rs + Rw + (Re/n))$$

Series-Parallel is uncommon, but tries to make the best of both worlds. It places as many e-matches in series as you dare accept the chance of not firing correctly and as many strings on these series connected e-matches in parallel as you need in total. It is also the optimal topology for firing the largest number of e-matches from a given source resistance. This is helpful if firing a large number of devices together, as in clustered rocket engine arrangements, or large fronts of pyrotechnic devices. Such an arrangement, or a similar one fitting the same model, may be mandated by the physical arrangement of long fronts with multiple daisy-chained slats.



$$Vs > (n*Ie) * (Rs + Rw + ((m/n)*Re))$$

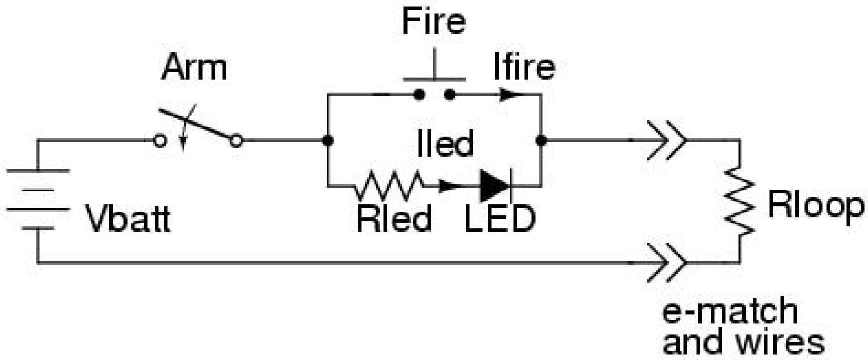
Practical Firing Boxes

A firing system can be as simple as a battery and a pair of wires which you touch to the terminals at the right moment, or a bunch of nails in a piece of timber (a "nail board" - handy for sequenced fronts). However, for safety it is best to have a somewhat more complicated arrangement. At minimum it is best to have a safety arming switch and a separate firing switch. The arming switch is best if it is physically difficult to press accidentally, a key-operated or shrouded rocker switch is ideal. The firing switch may also be shrouded for extra safety.

So called "shunt-plugs" are also a good safety feature, and are required by the standards in many countries. They simply short every shot circuit at the slat until just before testing or firing. Providing the facility to have a shunt-plug installed at the same time as a firing cable is useful, but risky in that someone may plug the other end of the cable into the firing box while you are up at the slat unplugging the shunt-plug. Generally a shunted lead is swapped for the shunt-plug and you take the key to the firing system with you out to the slat while performing the shunt-plug/firing lead swap.

Ideally your firing system should also have a continuity checking system. Activation of the continuity checker should be at the very least part of the arming procedure, if not a separate difficult to accidentally activate button. The potential exists in practical situations for the no-fire current being used to test the continuity to cook-off an e-match and prematurely discharge a pyrotechnic device, perhaps with lethal results!

Probably the most entry level firing box would be a circuit (per-channel) like this:



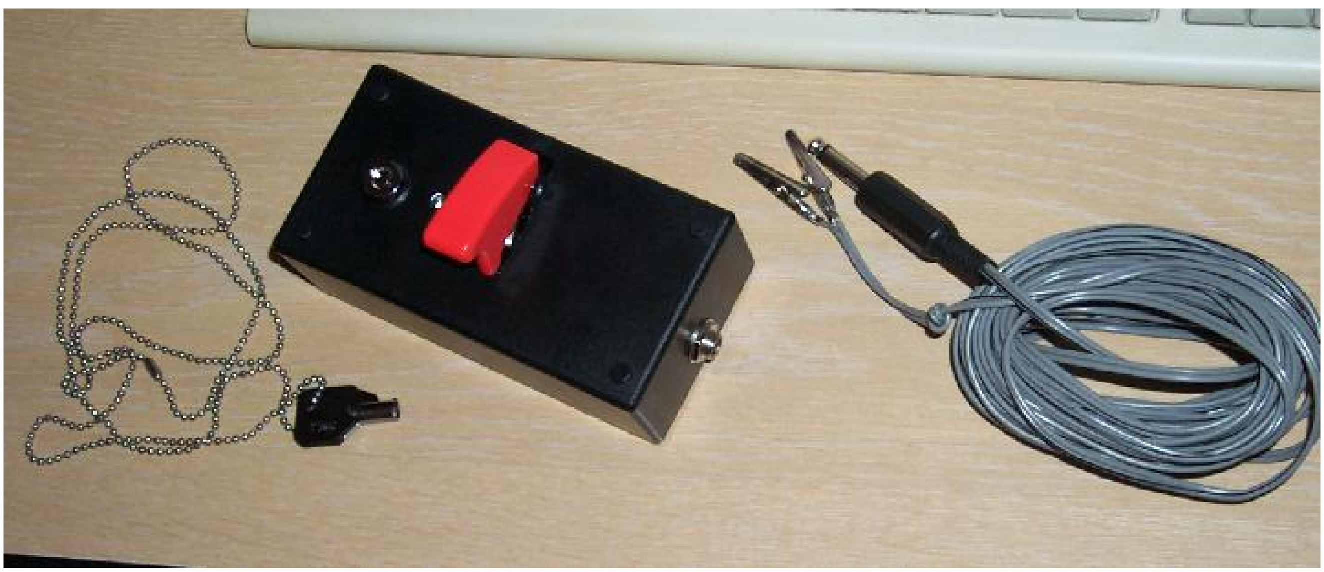
$$Vbatt > Ifire * Rloop$$

$$Rled > Vbatt / \min(Iled, Itest)$$

$$PRled > (Iled^2) * Rled$$

Vbatt is chosen such that it can deliver the all-fire current Ifire through Rloop. Rled is chosen such that worst-case somewhat less than the no-fire current Itest passes through it (ie, setting Rloop = 0). This current must also be less than the maximum the LED is rated for, Iled. Vbatt must also be greater than the forward voltage drop of the LED or else it will never light. The power dissipation of Rled can become significant at higher Vbatts, ensure it is sufficiently rated.

Here is a picture of a simple single channel system using such a circuit:

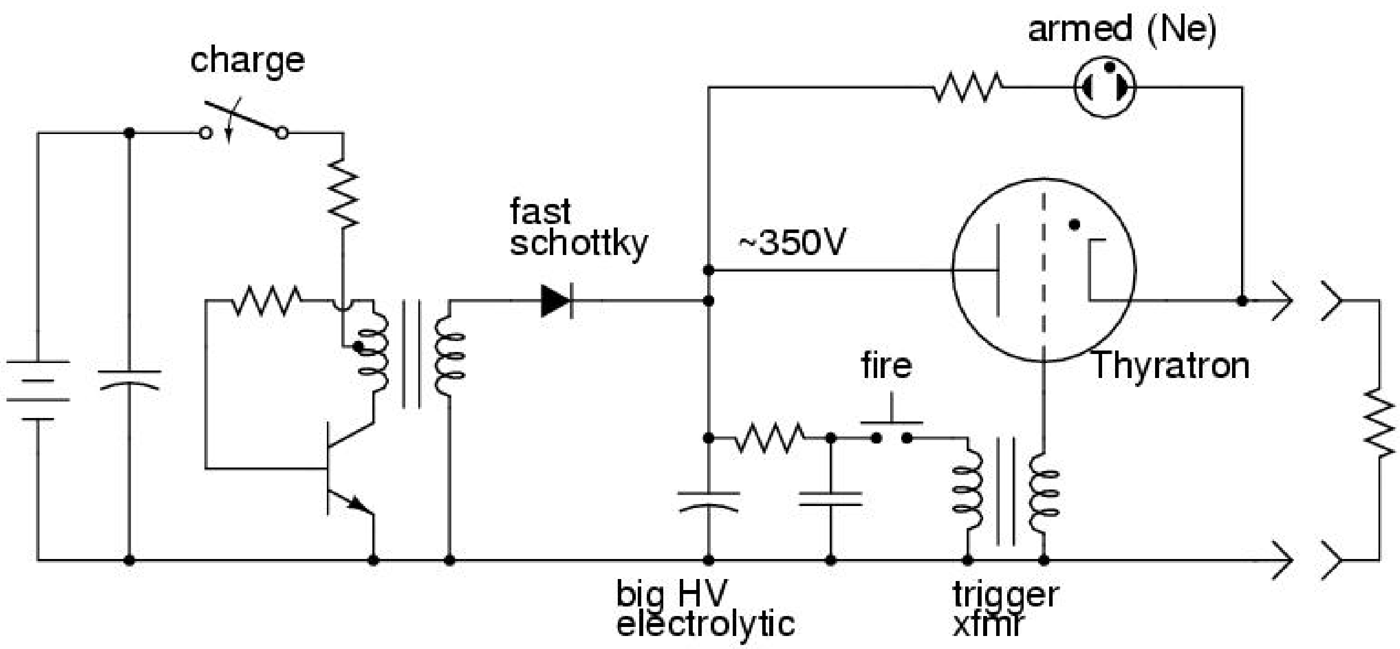


It is a simple matter to duplicate the circuit above as many times as required to build multi-channel firing boxes. Practical issues like quick interconnects between the firing box and the slats, and the slats and e-matches will drive the plug and socket selection. D-style data plugs are popular between the box and slats, they can take several Amps briefly which is more than sufficient for series connected e-matches. A D-25 system can carry 25 shots using the shell as the return, or 24 shots using one pin as the return. Multiple pins can be used for a single channel to boost current capability if required. D-type connectors make implementing shunt-plugs very easy. Spring-loaded speaker terminals are very popular for the slats, but some use binding posts for better mechanical restraint at the expense of somewhat longer set-up times.

Advanced Systems

Capacitor Discharge systems are becoming increasingly popular. They offer very high firing voltages and extremely low source resistances, capable of pushing large currents through even thin wiring. They are ideal for driving a large number of e-matches per channel at a great distance from the firing box. As smaller batteries can be used they offer a mass/volume benefit as well. Their charge-time and extra complexity tends to limit amateur construction, but modified photo flash units are easy to put together for single-channel use:

The unit above has a 130 uF capacitor which is charged to 340 V, delivering up to 7.5 J into the loop. The typical simplified circuit of a capacitive discharge firing box resembles this:



The HV capacitor(s) in such devices store **lethal** energies. Construction and use of capacitive discharge firing boxes is for experts only! There is quite a bit more to a successful circuit than show above.

Diode multiplexed, microprocessor controlled, computer driven, and RF linked systems are beyond the scope of this page, but much information can be found online about them. Anyone with sufficient electronics knowledge and attention to safety can easily build one for far less than the commercial asking price. Commercial systems are of course expedient and have some expectation of performance and reliability which many find very attractive. Be aware though that there are many commercial systems out there that are just terrible, either in design or build quality, frequently both. Quite a few builders of commercial systems found online have never used them in practice, or used them so infrequently that they don't have a good feel for making a practical rugged unit that will survive use in the hostile field environment.

Practical E-Matches

The simplest e-match is made by taking a suitable length of bell wire and bearing both ends, a short length of fine gauge nichrome is shorted across one end (preferably by soldering), and the result dipped in a slurry of black powder then allowed to dry. Almost all e-matches are also given a final coat of thick lacquer to protect and waterproof them, often nitrocellulose or cellulose acetate is used. The bare wires at the other end of the e-match are twisted together as a "safety shunt" for

Nichrome is not the only bridge wire material that may be used. Any metal that is ductile enough to be drawn into a filament sufficiently fine to achieve the required resistance in practical dimensions can be used. Nichrome is quite difficult to solder without resorting to acid-based fluxes (which require clean-up neutralization after use) so other metals are quite desirable. Folding and crimping the lead wires to the bridge wire is popular, but no substitute for a good pair of solder joints. Fine steel threads from steel wool pads or scourers work and solder quite well, and are very cheap compared to extra-fine nichrome. Very fine copper wire can also be used but I find it unmanageably small in practice.

A more sensitive pyrogen can be used to make ignition more immediate and reliable. Typical compositions are dark flash-like. Such a sensitive composition is always prepared as a slurry and is treated with the up-most respect. The smallest amount possible is used. Usually another layer of a less sensitive composition will be coated over the top to protect the e-match and give it better ignition qualities. Metal powders or thermitic mixtures are often added to generate long-lived hot sparks for their fire-giving properties, amorphous silicon or boron are also popular additions.

As the e-match head ignites from the inside they generally explode with a loud snap and throw burning pieces of pyrogen in all directions, this is where a shroud comes in handy to direct the blast where it is needed, and keep it away from where it isn't. The shroud also protects the sensitive e-match head from accidental friction and casual impacts. Crush damage is the most likely form of abuse to cause an accidental ignition, many commercial e-matches will ignite when crushed, stepping on them is generally enough to set them off.

Peroxides of Barium or Zinc are popular oxidisers for ultra-sensitive pyrogens. Barium Chlorate is quite popular too. One must balance their requirement for a "death mix" pyrogen with safety, most commercial pyrogen compositions are quite friction sensitive and can lead to nasty accidents while matching shell leaders, especially without a shroud or with it pulled back. Having sulfur containing blackmatch stabbing into the shroud-protected e-match head is probably just as dangerous. One school of thought suggests you match the shell leader while the shell is already in the mortar with all body parts well clear for the best safety, but I prefer to make less sensitive e-matches and beef up the firing system, it gives you that extra margin of safety against accidental ignitions.

Conductive pyrogens for bridgeless e-matches typically use conductive lampblacks and/or metal powders to form a "composition resistor" around the bare lead wires. The composition and the bare leader geometry is tuned to achieve the desired resistance. Acetylene black is very conductive and a popular choice, but more modern nano-structured carbon materials are now available and could be interesting to try. The bridge wire attachment is the most time consuming part of making e-matches, so bridgeless e-matches are very attractive. However they are generally considered less reliable and more difficult to make with controlled characteristics which makes them difficult to use in series strings.

Expedient e-matches may be made by soldering commercial 1/4 Watt (or less) low value resistors to a length of bell wire and then coating with a pyrogen. Surface mount components are gaining popularity. Other expedient systems use "grain of wheat" bulbs or Christmas tree lights as pre-wired e-match heads, almost ready to be dipped (the envelope is carefully opened before applying the pyrogen). Such a construction technique has quite a following in the amateur rocketry world. In the past Zr/Mg/O2 flash bulbs were very popular, those multi-shot flash bars and cubes were easily dismantled and the individual bulbs used. Narrow strips of PCB material, copper clad on both sides, are easily spiral wound with bridge wire then soldered the complete length. A fibre cut-off disk is then used to cut individual e-match "chips" that can be soldered to bell wire then dipped as usual, this is a very expedient way to make hundreds of e-match heads per hour.

As bell wire is becoming more difficult to get in Australia, I find using Cat-5 data cable pairs for e-matches quite usable. You can use stranded wire if you wish, but solid core wire is much easier to work with. Be careful, especially with bridgeless e-matches, that your pyrogen composition is compatible with the wire material, dry the pyrogen quickly to limit corrosion of the lead wires (and bridge wire), and then coat with syrupy lacquer for a good moisture seal.

Like commercial firing systems, commercial e-matches are expensive but extremely reliable. They offer very tight repeatable ratings, which is very important for series firing of large strings. For mission critical shots with cold batteries or long runs they are the only choice. **Never shoot a commercial display with homebrew e-matches**, it just isn't worth it! However being able to make a cheap e-match for testing things and other times when it just doesn't matter is quite useful.

2 comments.

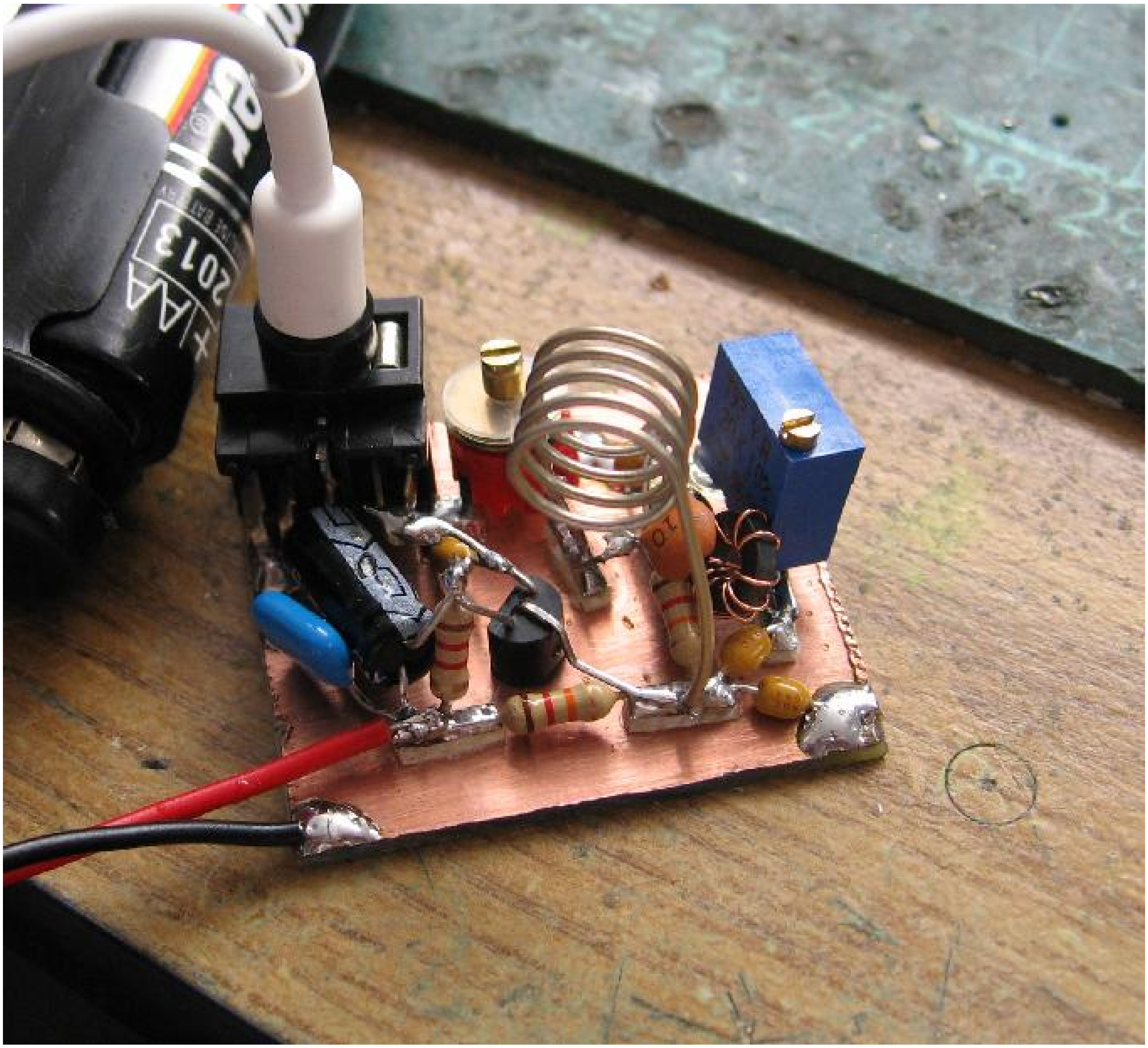
Attachments

title	type	size
ematch fig source	application/octet-stream	1.377 kbytes

Elektor FM Broadcast Super-Regenerative Receiver

2008-12-07

In my continuing procrastination in not playing with levelling loops I finally got around to building the FM broadcast receiver from September 2007's Elektor magazine. Peter VK2TPM saw this article and suggested it to me because of my well-known love/hate relationship with super-regenerative receivers.



The circuit appears in the "Mini Projects" section of the magazine and is credited to Burkhard Kainka. The circuit is fairly conventional in all but one way; it returns the emitter/source capacitor to the collector circuit to partially suppress the quench waveform from the AF output. The effect isn't perfect, but it does work fairly well.

The audio output into 64 ohms isn't very loud, as the article says, it works better with a higher impedance load.

of the final version to save space. The audio output is enough for listening in a quiet room. RF Performance is reasonable, but nothing special. My micropower FM receiver works better IMHO.

Google Translate is useful for looking at Mr Kainka's fine website. The receiver is mentioned here. Note also the regenerative receiver similar to his KW-Audion. It is very similar to my Noisy Regen, as is the KW Audion, except it uses an "infinite impedance" detector of sorts instead of the emitter current to recover the AF - something I must try myself.

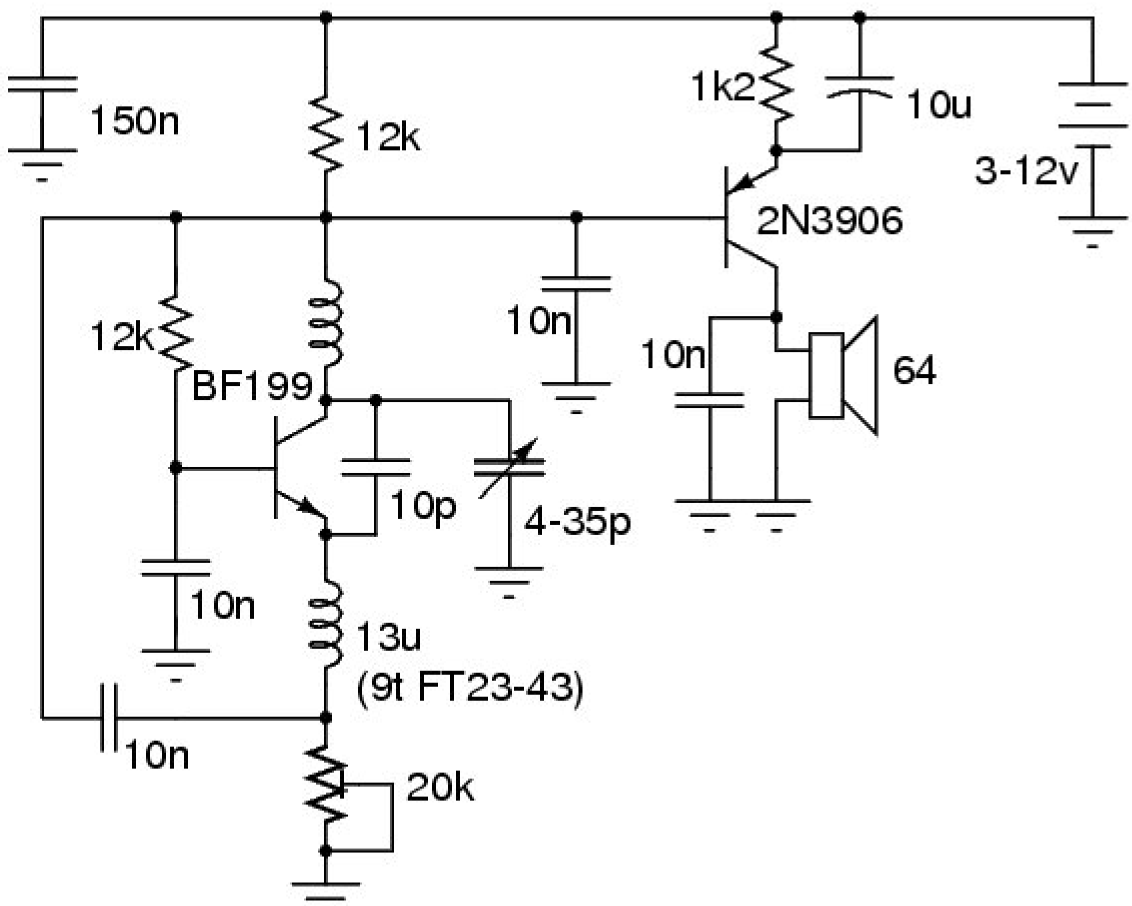
Build Notes

I did have some trouble convincing the circuit to super-regenerate properly, it was extremely fiddly to get a good quench oscillation going, and would take-off in UHF oscillations if I wasn't careful. The picture in the article shows - well - an abysmal layout, perhaps that is why the author's circuit worked better than mine - I guess too much RF hygiene can be a bad thing?!

Looking up with BF494 I found its Ft is only 200 MHz or so... This explains a lot, I used a BF199 which has a *much* higher transition frequency. I probably would have made it a lot easier on myself if I had used a "worse" transistor. I am still suspicious about my current batch of 10 nF caps. I have thousands of them and they are axial-leaded so I rather like building with them, but they have caused me trouble before... I tried swapping them out with 10 nF disk ceramics, but it didn't seem to help, so perhaps the collector circuit strays are responsible, I did use fairly long wires on the resonator coil. Anyway, I replaced the emitter resistor with a multi-turn cermet trimmer and was able to adjust the circuit with good usability without resorting to a different transistor.

The RFC suggested in the article killed oscillations above 90 MHz with the other component values suggested, but oscillation could be achieved by varying the emitter resistor and/or power supply voltage. I replaced it with 9 turns on an FT23-43 which works great to beyond 150 MHz in all configurations.

As built I used the following circuit:



It tunes from the VHF-Low channel 0 audio carrier (about 51 MHz) to about 150 MHz, covering the FM broadcast band, air band, 2 metres and the pagers just above it. More bandspread would be preferable, especially if dedicated to FM broadcast use, this is a major reason why I favour my micropower unit who's tuning is carefully arranged to cover just the 3 metre broadcast band.

The antenna may be applied at the emitter, but isn't really needed as the unshielded unit just sitting on the bench works fine with the local stations, even airband signals, Sydney approach being heard fairly easily... The

and the rail decoupling 150 nF (it might be preferable to add collector-base feedback instead of the collector cap as it might cause instability itself with the inductive collector load, but with my headphones it didn't). The frequency of oscillation was quite high, in the HF region, and was pulled by the headphone leads. Again a "poor" transistor would probably avoid this problem, but the BC559C specified is actually quite likely to take off itself without the capacitor. Using a BC559C is probably overkill for the quality of audio recovered by the regenerative detector.

Using a trimmer instead of the fixed 10 pF emitter/collector feedback capacitor is helpful if your unit misbehaves. It allows more precise adjustment of the feedback. In the past I've had some transistors refuse to oscillate except in very narrow ranges of feedback capacitance. This particular circuit was fairly well behaved, but I did at one point use a trimmer. 10 pF was near the optimal, so I replaced it with a fixed value.

13 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	15.441 kbytes

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Emitter Follower Regenerative Receiver

2009-01-14

I find myself really inspired by Burkhard's work. He experiments with some unique topologies and always comes up with something interesting to play with. Google Translate is as always very useful for reading his work if like myself you can't read German.

This receiver he calls the "The emitter-follower Audion". As usual he built it on a tinplate lid and uses a PC as the AF amplifier system. The unusual oscillator/detector topology drew me to it, naturally I just had to try it, being so simple it was easy to throw together.

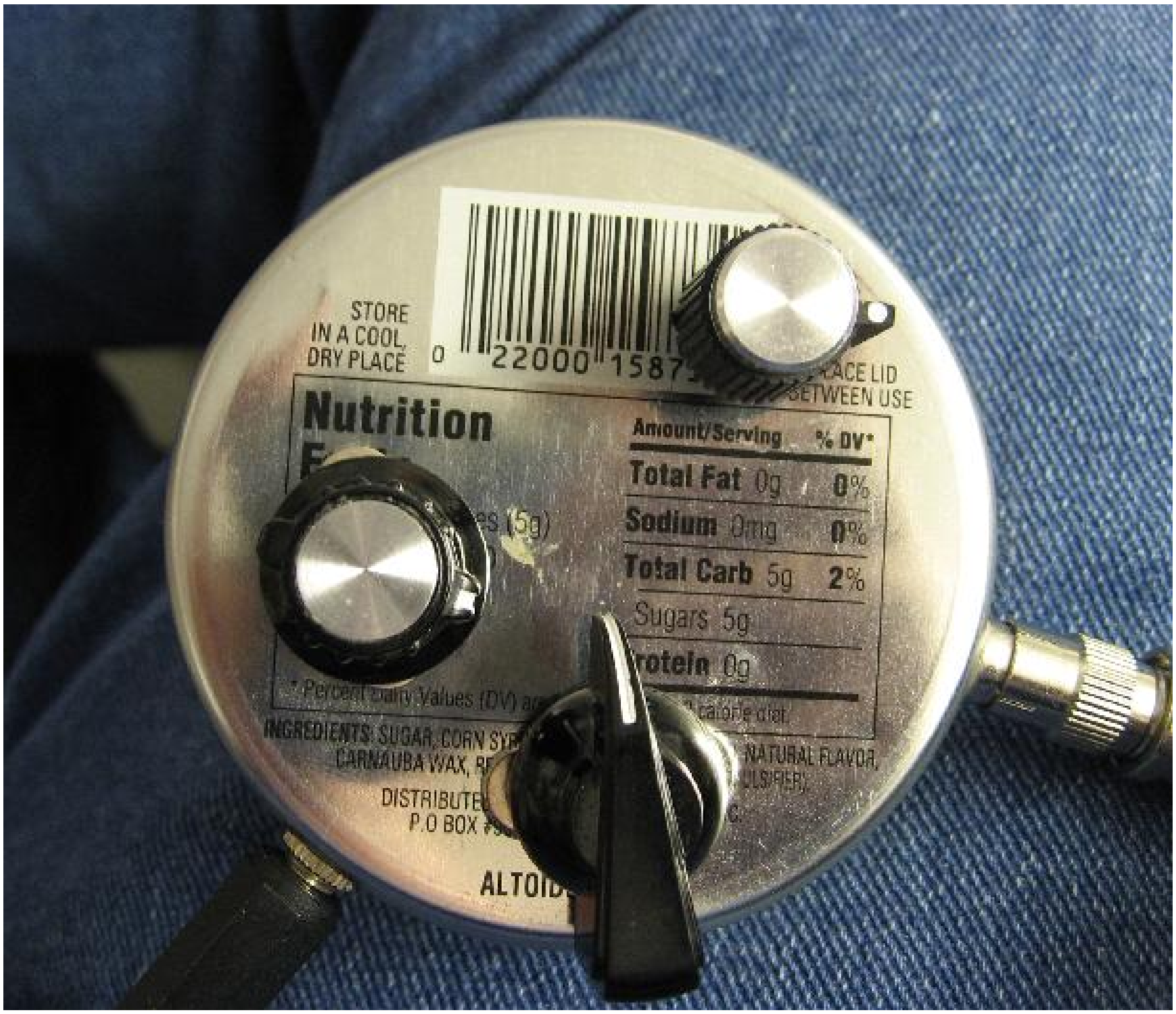
I built mine in a Altoids Tangerine Sours tin I picked up in Las Vegas. A 12 k switch pot was used for the regeneration and a pair of polyvaricons for bandset + bandspread tuning rather than a single trimmer capacitor, and a toroidal core inductor instead of a slug-tuned one. Otherwise I followed his design (except I used 2N390x devices, despite having BC-series devices in stock - I had the non-European transistors sitting on my bench, left overs from the dekatron emulator build - no other reason). The antenna connection was applied at a tap on the tank circuit (5th turn from the cold end through a 3p9 capacitor). The inductor value (about 5 uH; 32 turns on a T50-2) was selected using my LC VFO calculator to optimise the tuning range given the polyvaricon capacitance of about 210 pF with the gangs combined.

The radio works quite well. It tunes from about 4.8 MHz to beyond 23 MHz. Break into oscillation is fairly

 XHTML | CSS | CSS toggle

reception of AM broadcast stations. With strong signals it tends to injection-lock the carrier, becoming an autodyne-style receiver. Weaker signals can be resolved as hetrodynes in oscillating mode, and by using software on the PC I was able to mix-down either sideband of a weak AM signal using the receiver oscillating and off-tuned.

Stability is quite reasonable, but degrades as expected with increasing frequency. A more robust mechanical construction might help in this regard (flexing the tin shifts the frequency a bit), but long-term drift is actually very good, surprising considering a type-2 toroid was used. The regeneration control pulls the RX frequency quite a lot, which is not unexpected when the tank is so heavily coupled to the transistor. It might be interesting to tap-down on the tank the connection to the transistor base. The bandspread polyvaricon makes tuning in stations quite easy. It's "antenna" gang (160 pF) is coupled to the tank via a 10 pF, this might be reduced if you want to more easily resolve SSB signals. It would be very unpleasant to use the radio without the bandspread/bandset tuning, at least with weaker stations.



I haven't labelled the front yet. I'll probably calibrate the bandset capacitor (chicken-head knob) with the bandspread centred so I'll know roughly where it is tuned, at least highlighting the shortwave broadcast and HAM bands.

31 metres was very active during testing, and Radio Australia and Radio New Zealand dominated the band. Voice of America and China Radio International were easily heard. Weaker stations were a bit harder to tune in with Radio Australia overloading the receiver at times, a pre-selector would be helpful, but reducing coupling to the antenna is helpful and once the regen is tightened towards the onset of oscillation the detector Q becomes sufficient to reject adjacent signals, even ones within 10 kHz (like the pairs of RA transmissions). Many stations were not identified, carrying non-english content or failing to identify within my limit of patience for listening to rapid QSB.

This video is of Radio Australia in oscillating mode, showing the receiver injection locking to RA's enormous signal.

Some Music on Radio Australia
(5.974 Mbytes)

Naturally the receiver lacks AGC and rapid QSB on long-path signals can be rather annoying to listen to. However, for its simplicity you can't help but be rather amazed how well it actually works. As Burkhard suggests, it might be a great first-project for someone interested in building shortwave receivers, but direct drive of "walkman" headphones would be helpful, untying it from an external amplifier or PC. (I tried a crystal earpiece, which works but only with the very strongest stations). I might design a matching 1.5 Volt amplifier capable of driving 32 ohm headphones and build that into the unit, making it stand-alone.

10 comments.

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End-Fed Half-Wave Antenna & Tuner

2007-03-11

For the on-going 2007 ARNSW Homebrew Group Challenge work I needed a simple 80 metre antenna. As a home-unit resident the size of a full half-wave is pretty impractical, but I decided to try it so I had a base-line to compare future shortened verticals to.

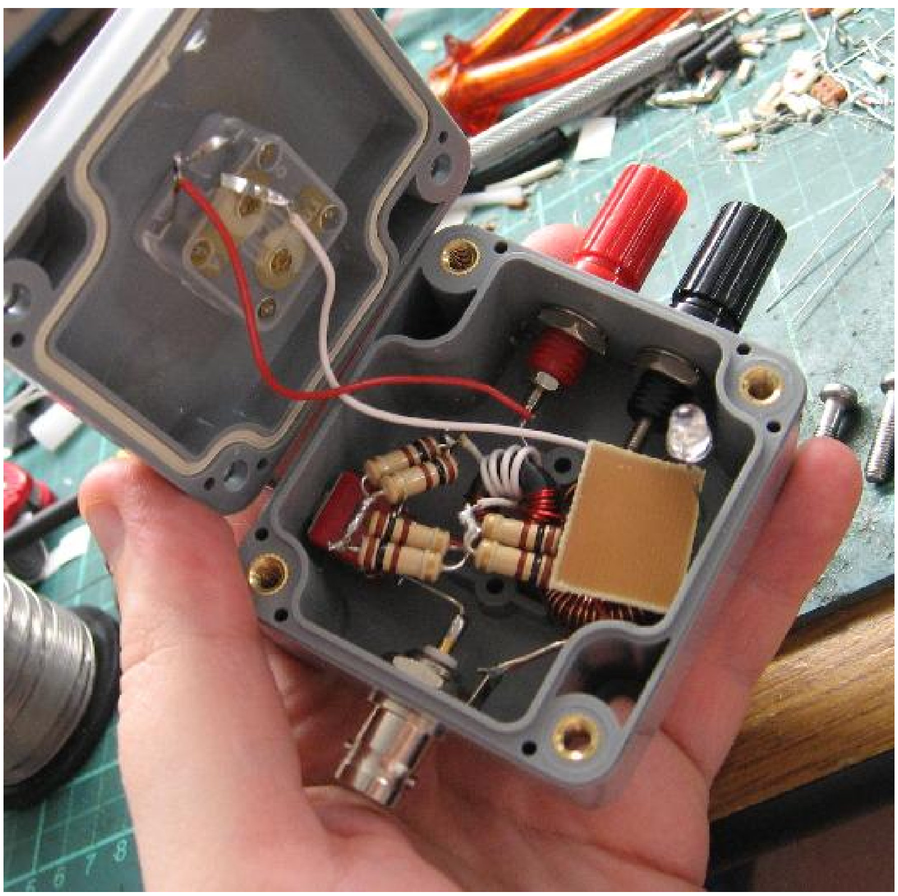
While centre-fed would be the simplest to get going and probably the easiest to install in a semi-permanent manner, I went with end-feeding. I would like to have the option of using the antenna portable, where a transmission line is just something else to carry and end-feeding is probably the easiest to set-up.

I read everything I could on the subject, the ARRL antenna book is good, but I found Steve Yates AA5TB's website especially useful. Steve explains the physics of the counterpoise well, and gave me confidence that it would indeed work as I had planned without stray-RF problems.

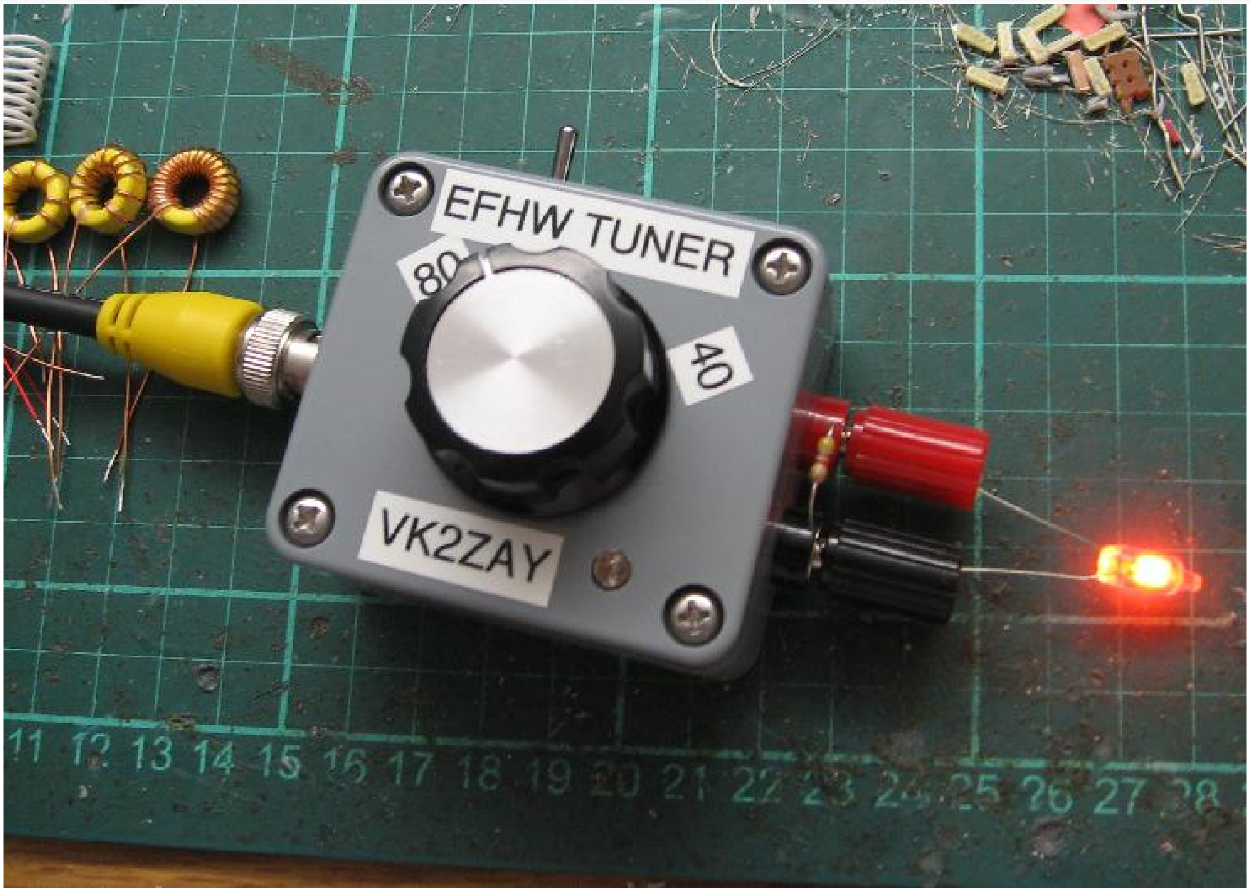
The Tuner

A matching box was constructed, containing both a matching circuit and a resistive 50 Ohm VSWR bridge that borrows heavily from Dan Tayloe N7VE (et al). The matching inductor value was picked to resonate the available variable capacitor gang just below 80 metres at maximum capacitance. The Hi-Z side floats to make it more versatile, a simple clip lead can be used to return the counterpoise side to the coax braid, if so desired.

The final device tunes a resistive load of 3-7 kilo-Ohms from 3.2 MHz to 12.6 MHz. 40 metres is covered (and 30 metres too, but I lack a transceiver for it currently), it is unfortunate that 20 metres could not be covered as well, without switching out some of the windings. W0CH switches his inductor taps, but this also changes the impedance match too much for my taste (Note that you can compensate somewhat for a few kOhms of resistive mismatch and an undetermined amount of reactive mismatch with the tuning). His circuit is otherwise very similar to mine (and just about everyone else's who has an internal bridge).



The unit was built in a small plastic box, and it was quite a squeeze to fit the tuner and the bridge inside. The resulting unit is very small and should work fine in portable operations. The tuner can be seen running about 1 Watt CW from the challenge transmitter into a 4k7 dummy load and a neon bulb which is getting stinking hot!



This gross abuse of a Neon bulb shows the voltage step-up of the tuner and proves it can feed a high impedance load fairly efficiently.

The Antenna

The radiator itself is simply a half-wave long piece of wire. I used an unzipped length of "zip cord", a full free-space half wave length (about 41.6 metres) which makes the antenna a bit reactive, but this is easily tuned out. Managing the wire while it was measured and unzipped was actually one of the more challenging parts of the project, but with the help of the XYL and the parents it took only 20 minutes or so. Black plastic egg insulators from the WICEN stand at Wyong were strung on the wire, two fixed at each end and two floating to allow various geometries for deployment. Banana plugs were added to each free end of the wire, so either might be used as a feed point.

Testing

After some trial and error it was found possible to just fit the antenna's enormous length on my property. The centre was strung up at my 3rd story bedroom window and the ends sloped down to the extreme boundaries, one being the car park railing at the edge of a cliff, the other being the adjoining property's fence. The car park end was the most practical to feed from, so I took some gel-cells, a few radios and a fold-up chair down to the cliff edge and set-up there.

The antenna works much better than any I've used before. The inverted-V configuration may have something to do with this. I used the railing around the car park as a counterpoise, but it was possible to run using just the radio and its coax as a counterpoise too, by clipping the counterpoise connector to the coax socket outer with an alligator clip lead. It was very easy to tune in either way, on both 80 and 40 metres. The ARNSW morse practice beacon was full-scale on my VR-500, were normally is is barely S1 on my north-south horizontal 40 metre dipole. With a homebrew 80 metre transceiver I could hear lots of DX and local QSOs, and I listened to the WIA broadcast using my 80 metre VXO receiver for the first time at a good signal level. As the sun went down the mosquitoes got too bad to stand any longer, so packed up and went back indoors.

I had to take down the antenna, it is simply too big to leave up all the time, if I want to keep the neighbours on side anyway. The car park end is also a bit of pedestrian hazard, so this antenna will only be going up for special occasions. The experiment was otherwise a complete success, and I am very impressed with the antennas performance. I also now have good figures to shoot for with a shortened vertical.

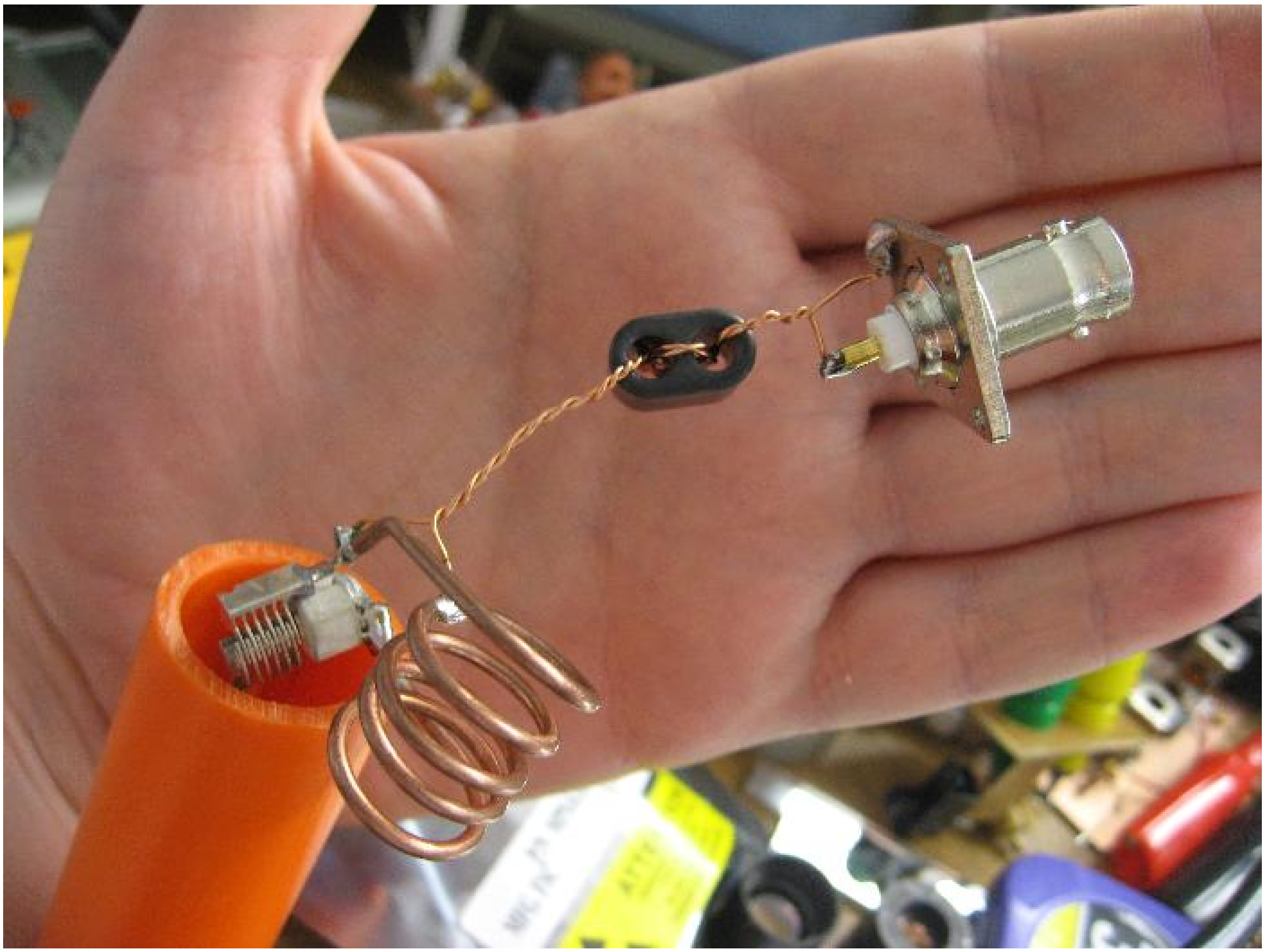
5 comments.

End-Fed Half-Wave for 2 Metres

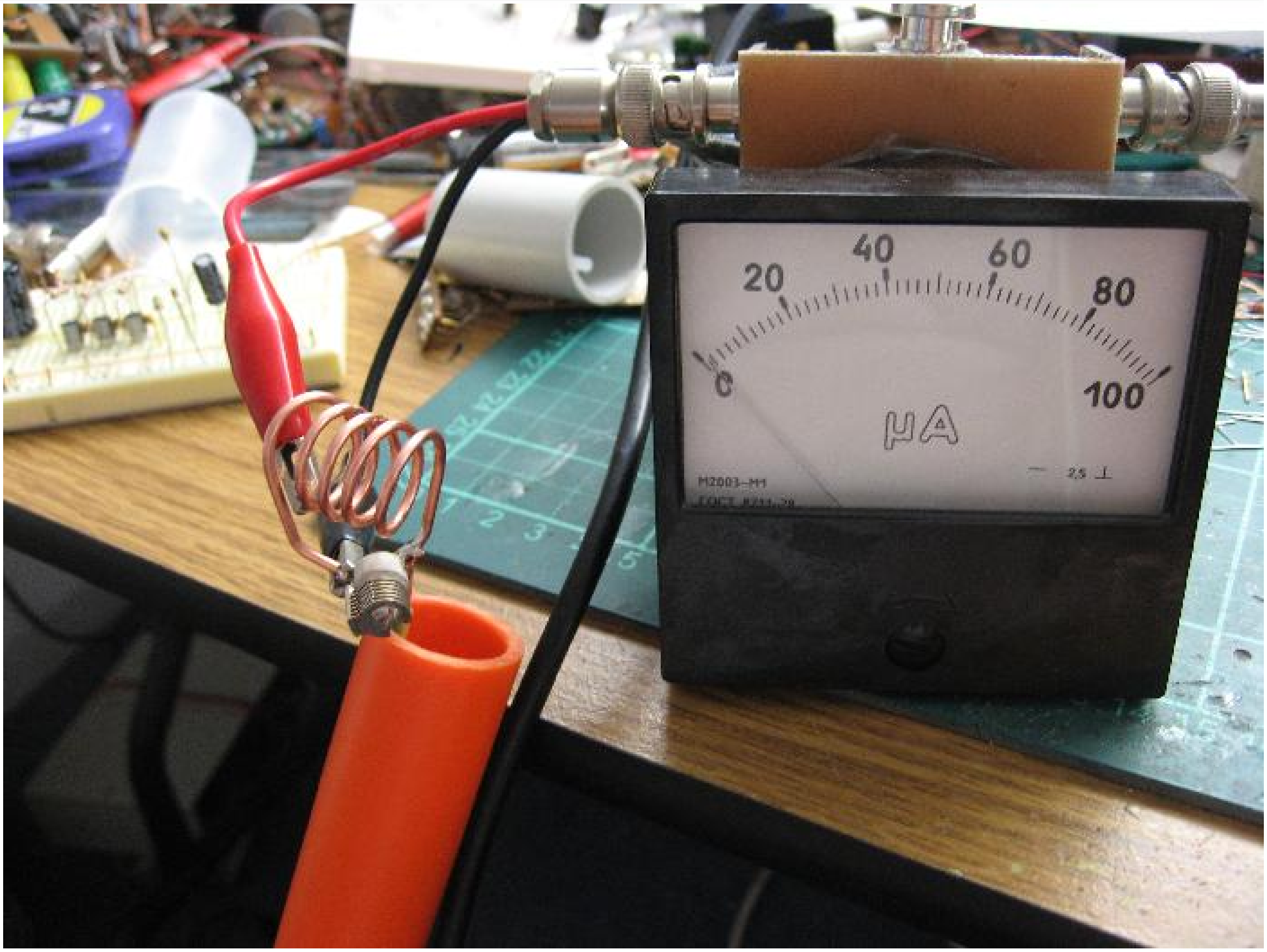
2007-06-02

I threw this antenna together while playing with the Fredbox transmitter. I wanted a reasonable radiator for stuffing around, but without tying up the main half-wave on the balcony.

It is simply a half-wave radiator fed at the end with a matching network comprising a tuned tank. A balun is provided to decouple the feed-line, and the match to coax is affected by tapping into the tank coil near its cold end. It is hung by a string when used.



The tuning is pretty sharp, but once tuned has reasonable bandwidth and offers an excellent match to 50 Ohms. The radiator is a piece of mains cable earth (multi-strand), cut for the harmonic centre of 2 metres. The coil is a bare piece of the active conductor from the same cable, 5 turns well spaced on a AA battery. The trimmer is a 2-9 pF air-space unit from Rockby.



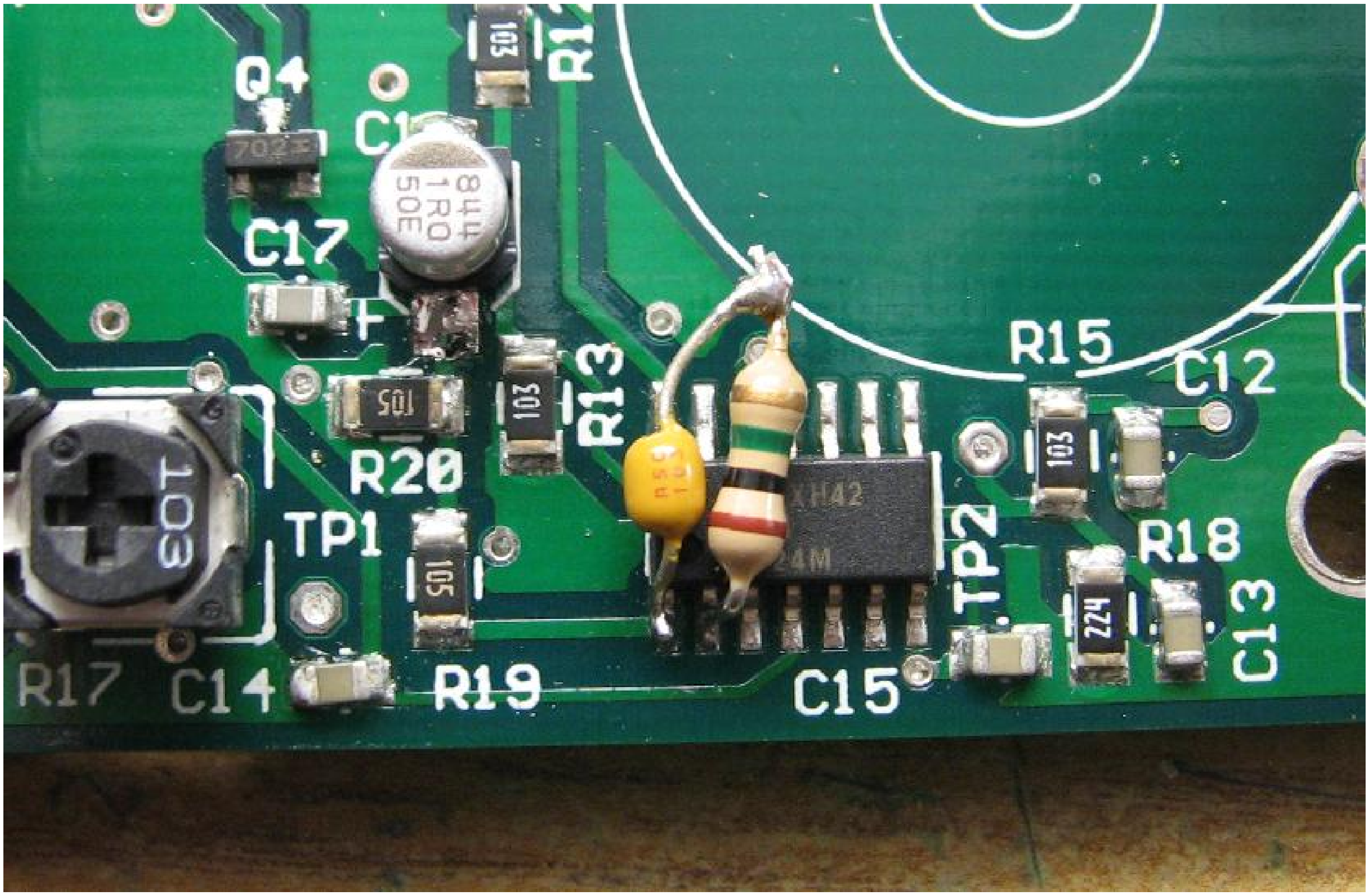
Power handling is likely limited by the trimmer plate spacing, and the balun core saturation. It works fine at QRP levels.

4 comments.

Fixed the MFJ-207 FM Problem

2008-12-23

Upon hearing that other HAMs have MFJ-207s free from the FM modulation problems my device shipped with I decided to take another crack at fixing the loop. Inspired by the design of the MFJ-269's ALC loop I simply added an AC feedback network to the LM324 lowering its AC gain but leaving DC unaffected. A easy, two component fix: 10 nF cap and a 1 Meg resistor, in series from pin 1 to pin 2 of the LM324 (output and inverting input).



After this addition I reset the ALC loop control point to that indicated in the manual. The oscillator is now nice and quiet, with only moderate noise sidebands, no more FM!

This fix does nothing about the buffering issues. The oscillator is still pulled around by the load on the bridge (and counter output), but it is now much narrower and suitable for use as a stand-in signal generator. It still doesn't particularly like narrow loads, but it is far more usable.

I took the opportunity to more carefully test the SWR scale. To do this I constructed a series of precision dummy loads into BNC connectors. I've been meaning to do this for a while, and have been getting by with a cermet trimmer pot wired to a BNC, these spot loads are much more expedient and allow doing a calibration (especially of the MFJ-269) in only a few minutes. I lacked some of the smaller resistors in sufficient precision, so I took the next smallest preferred E12 value I had and filed away part of the film until the required value was achieved. The file knick was then filled with liquid electrical tape to prevent ageing effects on the exposed element edges. I was careful to null my multimeter and use the most accurate one I have which seems to be around 1% on the 200 Ohms range when compared to voltages dropped across the similar power resistors.

The 207's SWR meter calibration is still utterly abysmal. You can only adjust it so one load resistance gives an accurate reading. Even reciprocal loads like 100 and 25 ohms, both 2:1, produce quite different readings. With loads on the lower side of the reference 50 Ohms the bridge seems to read low. Doesn't detract too much from its usefulness when tuning up a matching unit, it still dips sharply at 50 Ohms.

2 comments.

Parent article: MFJ-207 Review.

Alan's Lab

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FM Broadcast Band Transmitter

2001-11-25

Building my AM broadcast loop antenna brought back old memories of being an FM broadcast pirate while I was at high school. So, figuring I've learnt a lot about VHF engineering since then, and having a evening to kill I assembled this half-watt transmitter out of whatever I had laying in the junkbox.

I am not going to provide the circuit diagram, at least not until I have it all stable and nicely engineered. I'll probably be besieged by requests for it, just as I am as a result of the page about my pirate days. Let's face it, a lot of us started of this way, and I am not shy about admitting that I was once a pirate. While licensing is preferable to anarchy, I don't mind seeing interested people building their own gear for any RF frequency, at any power level. Provided of course, they don't hurt anybody, or themselves in the process.

The design is a simple free-running VCO which runs at the transmit frequency of about 94.5 MHz. Coarse tuning is made via the red tuning slug of the VCO coil, fine tuning is available via the small pot also visible in the photo. The fine tuning voltage also effects the sound quality as it controls the bias on a tuning diode (a simple 1N4001), the wiper is also connected via a DC blocking cap to the input audio signal. The bandwidth is many MHz.

The VCO is almost a power oscillator, running at many milliwatts, about the limit for the 2SC710 used to implement it. The signal is then coupled into a two state driver and simple tank filter, followed by the C-class output stage consisting of a 2N4427, an RFC, and a pull-down resistor, (and not much else except decoupling of course). There is a simple PI filter on the output to suppress any harmonics, but there really should be a better filter, with notches at the harmonic points, the final stage is fairly dirty resulting in barely -36dBc of the first harmonic.

Stability is excellent, there are no spurious signals other than the harmonics. The shielded VCO coil makes for excellent stability as well. It is firmly soldered to the board so even mechanical abuse causes little drift. There is however quite a large thermal drift before equilibrium is achieved, this is to expected for a VCO running at such power levels, the 2SC710 is getting quite warm.

I've made a simple ground-plane antenna for it out of some copper wire and a panel mount BNC. Most of the time the unit is plugged into four 220 Ohm carbon resistors in parallel, but at least once I've hung the antenna from the roof of the office, plugged the audio line into the sound card turned on some copyright music and took off down the street with a Walkman to see how well it gets out. It gets out *very* well for such a primitive design, it was still pretty much 100% quieting when I decided I'd walked far enough and turned back.

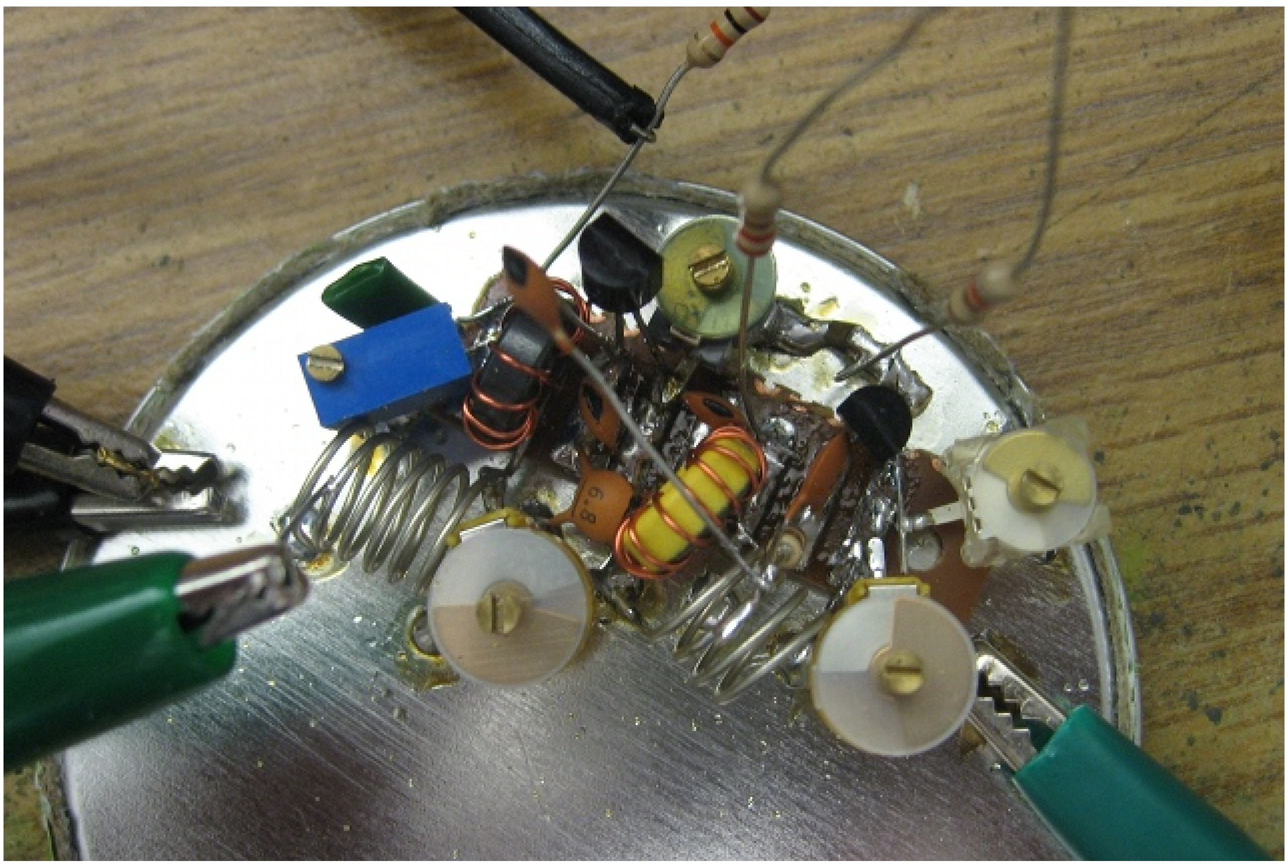
4 comments.

Fremodyne VHF AM/FM Receiver

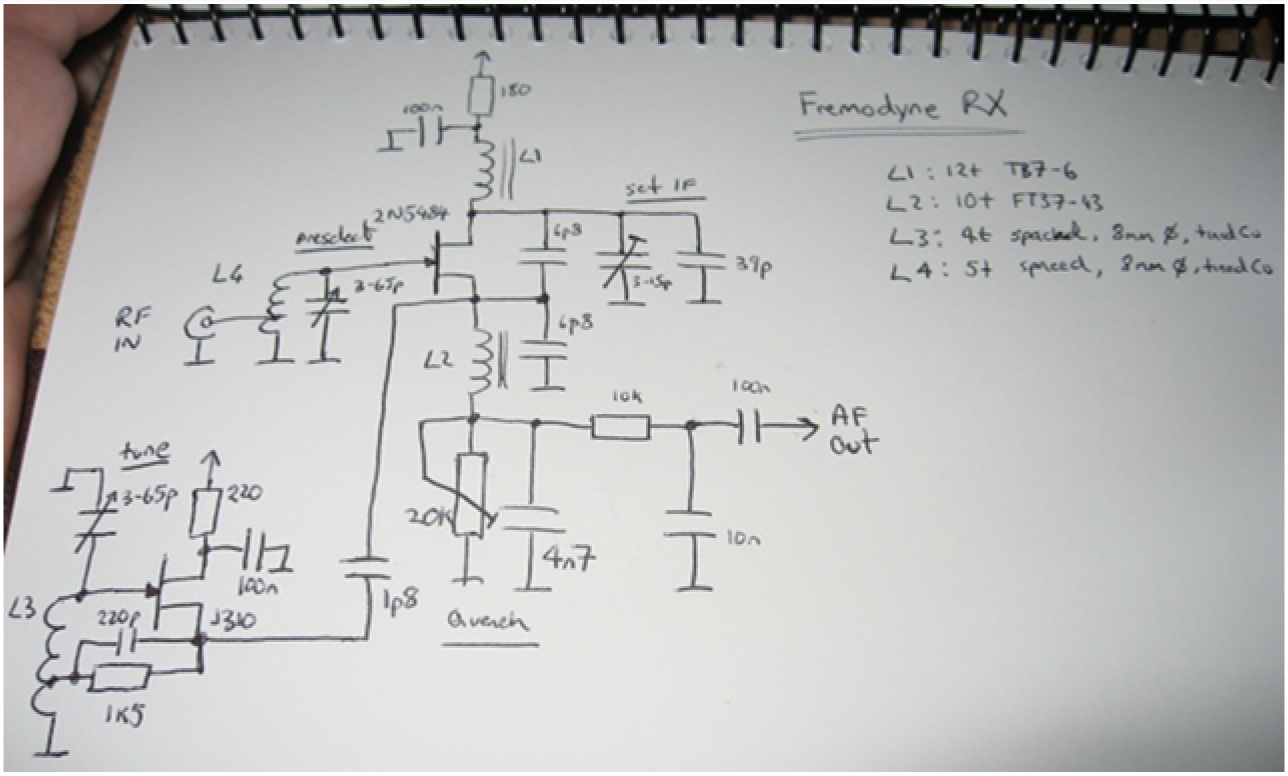
2010-05-23

The Fremodyne is a type of minimal super-heterodyne receiver intended for FM reception. It utilises a super-regenerative IF detector which doubles as a mixer stage. It has a long history, that began with vacuum tubes back at the beginning of FM broadcasting when a cheap receiver was needed to fill the lower-end market of receivers for the new FM services. John Hunter has an excellent site covering Fremodyne Receivers.

While the great majority of published designs are for vacuum tube devices my interest was in building a solid-state version for fun. This little experimental radio is the result of a quick back-of-the-envelope design during my commute to work, and a few hours of work on a late Sunday evening. It was intended to be an experimental receiver purely to work the bugs out of the design, so no effort was put into calibrating its tuning elements. Physically, the ugly hack was built on the tin-plate bottom of a Pringle chips can with a fragment of PCB edge connector glued to it acting a bit like a tag-strip.



Despite having no in-built AF stage and needing about 6-8 volts for the detector to oscillate well, it is quite a good little receiver. It is sensitive enough to pick up all the local FM stations (even with little or no antenna) and works quite wonderfully on the air-band and TV-audio channels. Like all minimal self-quenched designs it is basically impossible to completely eliminate interaction between the quenching of the detector and the FM multiplex signal. A multi-turn trimmer allows positioning the quench frequency so as to minimise any objectionable squeals mixed down to base-band, but the modulation of the oscillator operating point by the super-sonic multiplex signals produces intermodulation distortion and rumbling effects that are rather annoying to listen to. With monophonic signals this does not occur, and with AM signals one does not need to tune off centre to slope detect and gains a little more sensitivity from the IF.



The circuit is quite straight forward, but has a number of adjustable elements which makes this unit challenging for beginners to operate (Ironically exactly the opposite of the original point of super-regeneration). The quench adjustment can be set and left if AM and mono FM content is being received, but will almost always need to be tweaked when listening to a stereo signal. The quench frequency is a strong function of the received signal strength, so this adjustment is best performed last, mercifully it does not pull the IF detector frequency too much, so retuning for optimal slope-point is generally not needed. The front-end pre-selector adjustment on the other hand can drastically change the signal seen at the detector and alter the quench, so it is best to set it first. The pre-selector tunes fairly sharply, I roughly set it by dipping with the tone-dipper, then more precisely once a signal is being received by maximising the quench frequency observed on the oscilloscope. You can still tune about a bit either side with reduced sensitivity without touching the pre-selector, definitely enough to locate signals of interest before re-peaking if so desired (the radio works fairly well with the strong FM broadcast band signals if to just centre the pre-selector at 100 MHz and hope for the best). The LO frequency adjustment is quite straight forward, it must be set at +/- the IF frequency (or a harmonic) from the signal of interest to mix it to the IF. There are two trimmers offered, a coarse band-set one, and a finer band-spread unit (not in the circuit diagram, 1-7 pF) which is very helpful for positioning an FM signal correctly for nice slope detection. The receiver may be operated at either high or low-side LO injection, low side tunes easier (more band-spread), high side has better image rejection. The pre-selector determines which image will be favoured. The IF detector tank has a trimmer too, which can be used to precisely set the IF frequency if so desired. I run it at about 28 MHz which is near optimal for FM broadcast band reception, causing no in-band spurs.

Notes

Building something similar is easy. There are no special parts, almost everything is junk-box sourcable. The toroids used can be replaced with air-coils at some increase of physical size. The source RFC is non-critical and need only be about 10 uH, just make sure its SRF is > 30 MHz. The receiver is quite forgiving, the only critical thing is getting the IF detector to super-regenerate, you may need to tweak the Colpitts feedback (the two 6.8 pF capacitors) if it refuses to squegg at any reasonable voltage and setting of the source trimmer. Like all super-heterodynes test equipment is very useful, but by no means mandatory. I originally used my signal generator as the LO before I built the Hartley oscillator onto the board. My tone dipper and VHF wavemeter are the main tools I used to play around with the circuit - so no digital gear is really needed if you have some experience with VHF work. An oscilloscope is darn useful for checking the quench action, but an audio amplifier will tell you when it is working right.

Layout is surprisingly non-critical for a VHF circuit, my first version of the IF detector was built on a solderless breadboard and worked fine - the IF is only high-HF so it somewhat less demanding. The LO needs fairly good layout, it operates at mid-VHF, but being a Hartley is rather hard to mess up (it also generates way more LO energy than needed, you can decrease its current consumption quite a lot and still have sufficient injection amplitude). The gate pre-selector circuit is also ideally built using good RF hygiene, but initially to prove the IF

at the gate rather than a tuned circuit. You could just as easily use a resistor, but high-value resistors inject more broadband noise into the circuit and really high values allow stray signal pick-up, including AF which will be followed to the source and straight into the audio amplifier.

The LO tunes 54-183 MHz. This means with a suitable front end resonator it can tune 26-155 MHz with high-side injection and 82-211 MHz with low-side, assuming you hold the IF at 28 MHz. Various spurs will be seen through-out the range however. The IF detector really misbehaves when the pre-selector resonator is tuned to the IF or LO frequencies, generally dropping out of oscillation completely or the quench becoming audible and/or chaotic.

Ideas

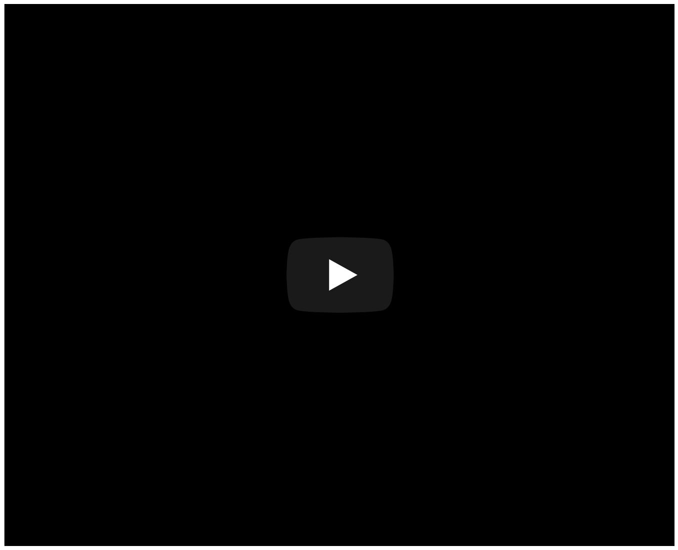
Clearly the mixing function can be performed in an extra transistor, this may reduce IF leakage and may improve IF rejection. Adding band filtering, buffering and amplification of the RF would be a good idea for a real receiver and may improve LO leakage. Separate quenching is worth experimentation, in particular this should help with the inherent distortion and intermodulation effects associated with the self-quenching detector. Digital control is something I am actively working with, and using an MCU to control the quenching allows easy RSSI and squelch integration.

2 comments.

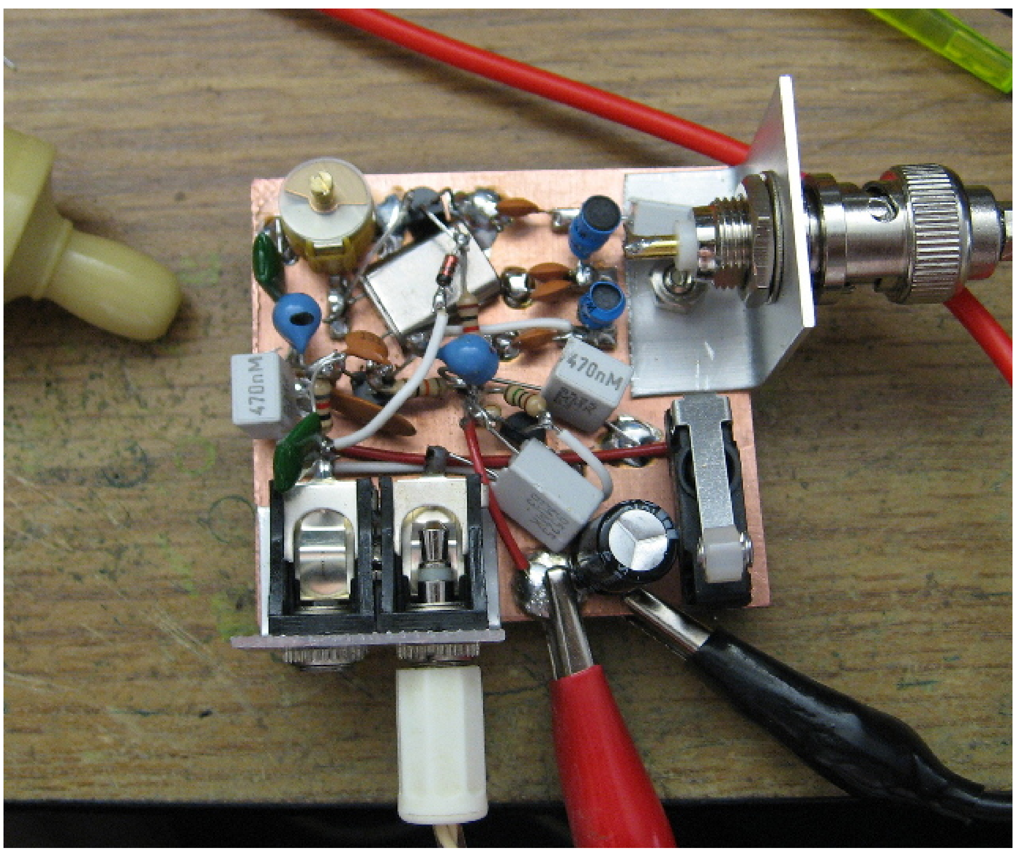
G3XBM's XBM80-2 Trivial 80 Metre CW Transceiver

2010-02-07

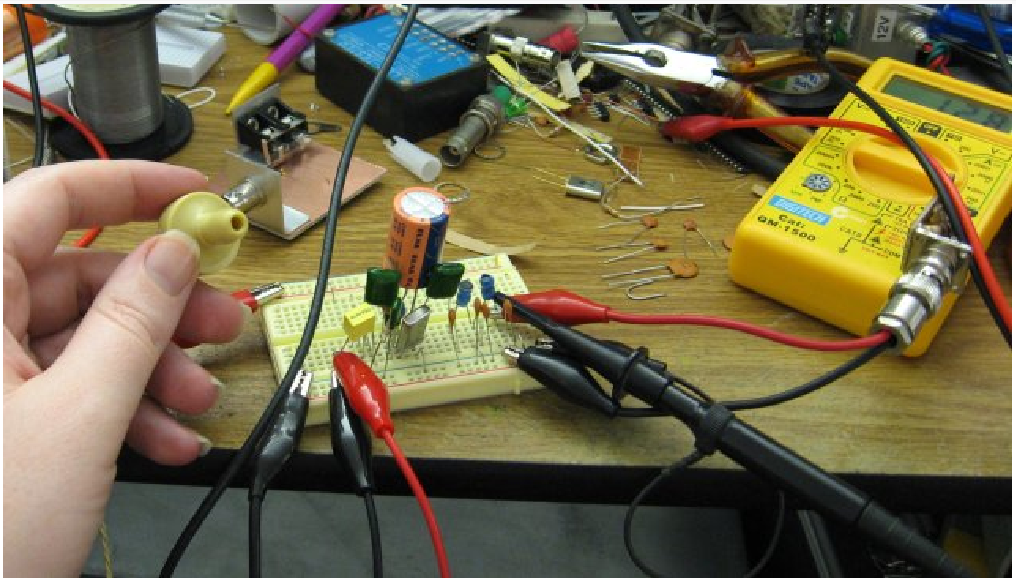
As a keen subscriber to Roger's blog, I've been following his and his audience's work on the XBM80-2. It is such a neat little transceiver, I just had to build one myself eventually.



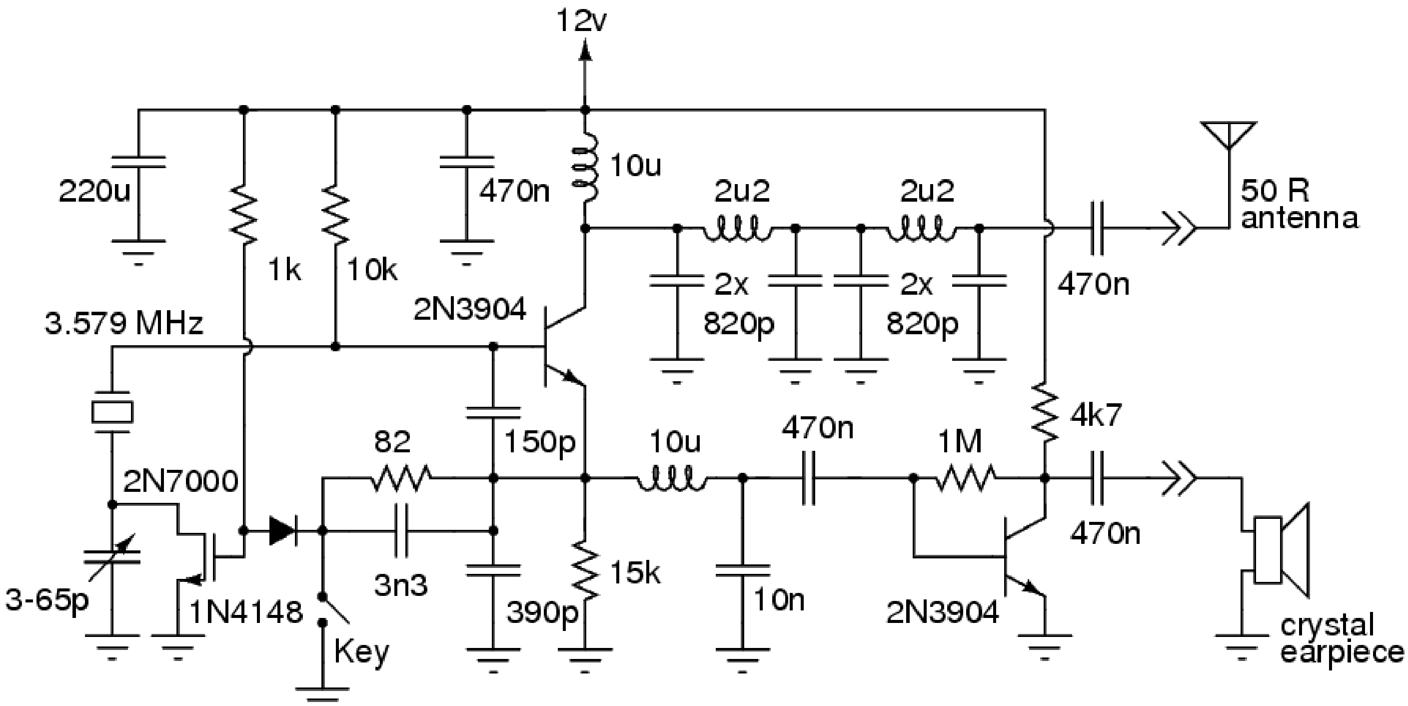
Of course it is a little ironic that I built a CW transceiver, when I can't RX CW! More incentive to learn.



I initially bread boarded the vanilla circuit which works fine. Investigating the performance of the circuit as specified by Roger gave me something to compare any customisations against.



Naturally though, I ended up making my own changes in the more permanent version after fiddling with the bread board version:



VK2ZAY's version of the XBM80-2 by G3XBM

My Changes

- Raised the lower feedback capacitor which improved the power output for my unit quite a bit. Unfortunately this also decreased the RX sensitivity, so I moved the extra capacitance into the keyline to prevent it affecting RX. You may need to RF bypass the keyline as a result. I added a microswitch on the board to act as a rudimentary Morse key, but also provide a keyline jack.
- Added a low pass filter to the antenna line. Michael AA1TJ used a band-pass filter in his version which is probably an ever better idea, but I was being lazy and used commercial RF chokes in a simple Q = 1 Pi configuration. Without the filter the output waveform was positively square! The harmonic energy is vastly reduced with this modification. The losses of the tiny chokes and vanilla capacitors are minor, there is little reason not to add these 6 parts, no toroid winding required, no tuning. (Although you can use 22 turns on T50-2's if you don't have the chokes in stock).
- Used a 10 uH commercial choke in the oscillator collector instead of a tuned value. The value is not critical, it should just be large with respect to the 50 Ohm load seen. 10 uH is about 200 Ohms, larger values are OK, but self resonance can be a problem with commercial chokes - I tried a 500 uH homebrew inductor at one point; worked fine. I did try tuned circuits in the collector but my oscillator was seriously upset as resonance was approached, even with de-Q-ing resistors.
- Added a LPF in the audio path to keep the RF out of the audio amplifier. Without this mod the audio amplifier was misbehaving on TX and worsening the harmonic radiation of the circuit. I toyed with the idea of making the filter series-tuned at 700 Hz to give some AF selectivity, but the required values I did not have and the large inductors required (88 - 100 mH) would likely be largely capacitive at 3.5 MHz. Still this might be worth a try, maybe fronted with the smaller RFC and cap to remove the RF first, or perhaps Michaels method of transformer matching into sensitive headphones and omitting the AF stage altogether is better?

- Added an automatic TX/RX frequency shift circuit. It adds complexity and a tiny bit of chirp to the circuit, but avoids the hardware T/R switch. The off-keying is a bit sharp IMO, adding a large capacitor across the keyline helps but worsens the chirp associated with my auto T/R change, so I omitted it. The on-keying is naturally soft because of the circuit time constants. The T/R transients in the AF output are annoying, but I couldn't do much to suppress them without making the circuit much more complex.
- I used 470 nF coupling caps because I have a lot of them. The value is valid where it is used, but frequently larger than the minimum required.

2 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	18.068 kbytes

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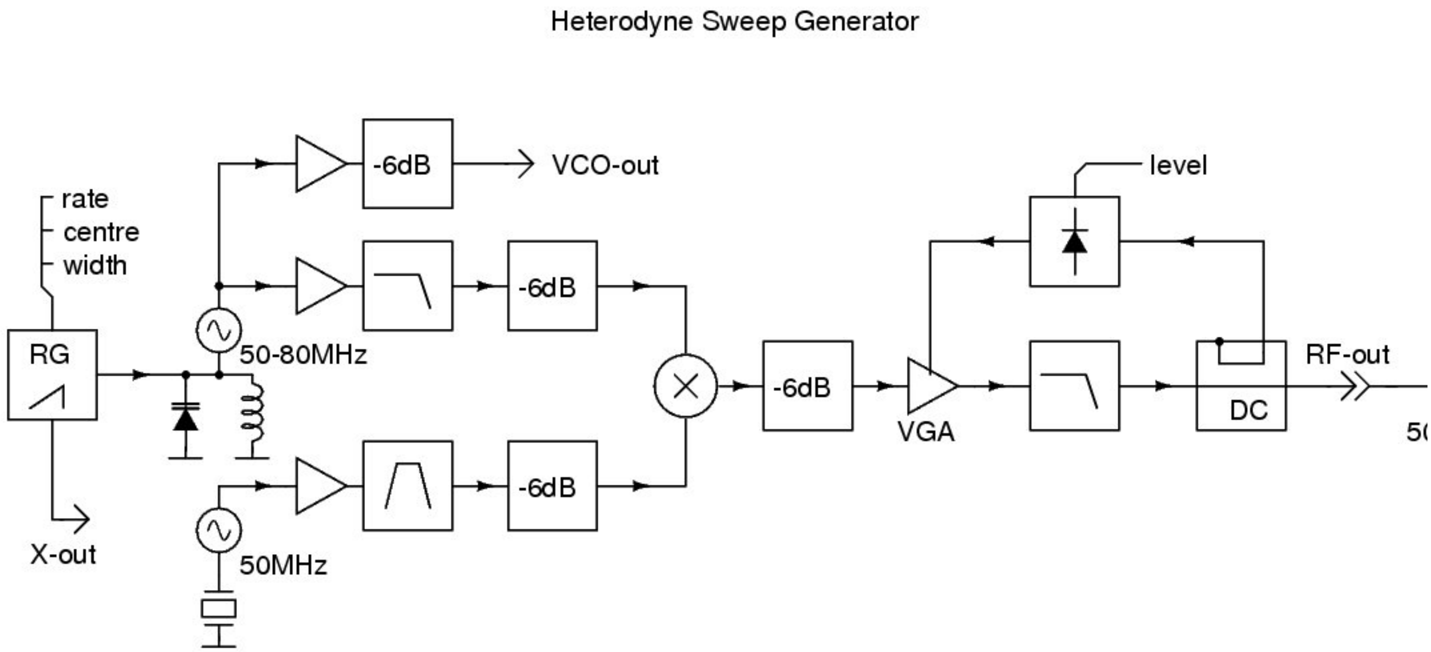
Heterodyne Sweep Generator

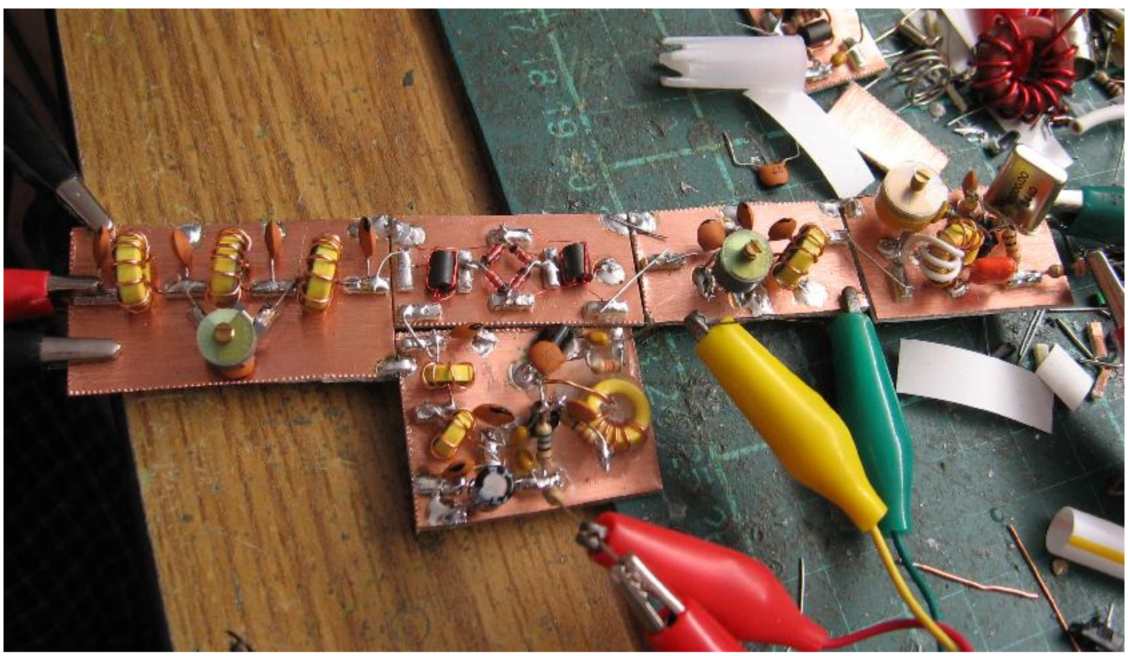
2008-11-23

Now days one would probably use DDS to implement such a device, but I wanted to build it the old-fashioned way to work out roughly what I'd face building one that sweeps much higher, to at least 150 MHz... The resulting HF instrument won't be useless itself and will be stand alone requiring no PC to drive it.



The sweep generator is quite simple in design. It mixes a 50 MHz xtal oscillator with a 50-80 MHz VCO then filters out the difference product and amplifies it to a constant level with a levelling loop. While quite straight forward to draw on paper there are a quite a few details that need to be carefully considered to get good spurious-free output from it.

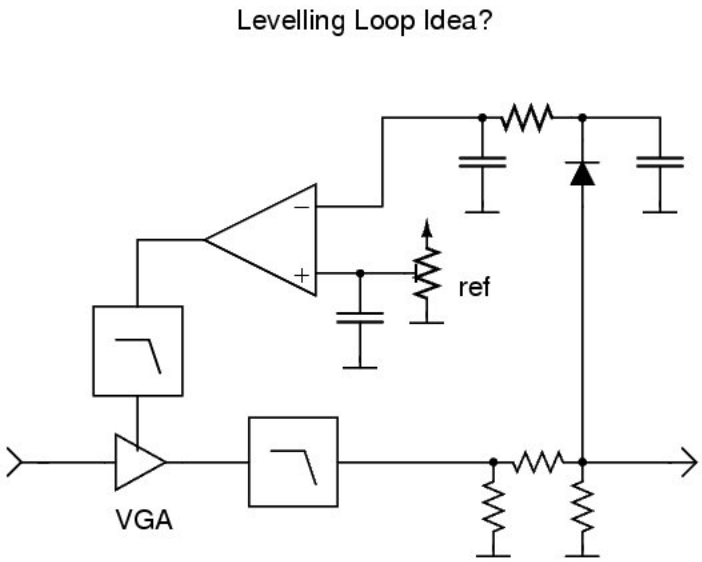
I've gone overboard with blocks in the block diagram, adding lots of pads and buffering amplifiers in an attempt to achieve good clean performance. How many of these will actually be required to make a useful instrument remains to be seen. For now I've started with the key modules, the xtal LO and VCO, filters and the mixer. These 6 modules can be lashed-up in a crude fashion as a proof of concept, which is what I have done (in fact I initially left out the oscillator filters, building the LPF first).



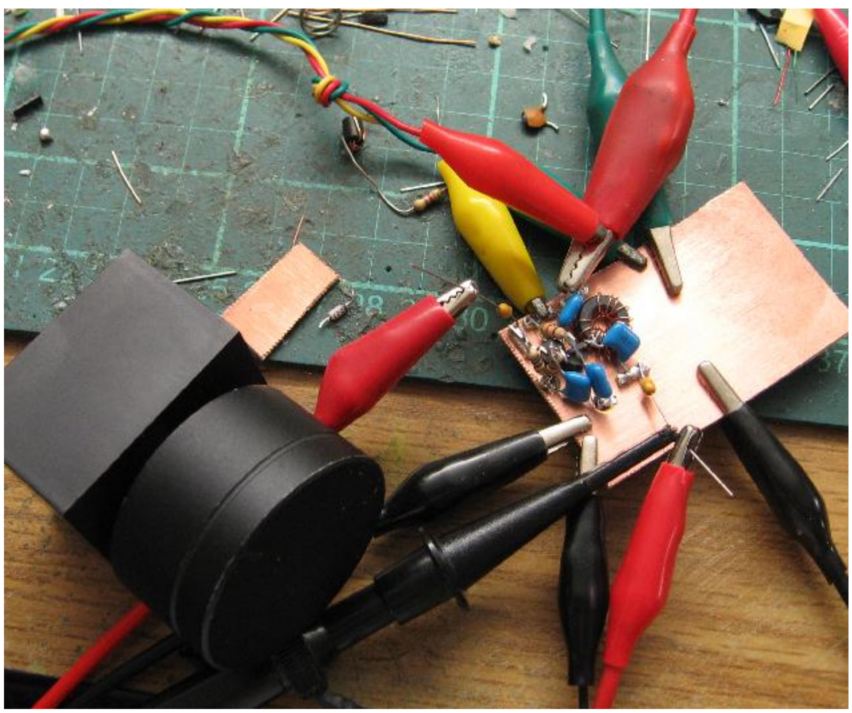
The result you can see in the video, a practically DC to 33 MHz swept source with pretty good flatness even without the levelling loop. My CRO bandwidth is only 20 MHz and its roll-off is much more significant than the level change until 28 MHz. The unshielded prototype is a bit buzzy, the VCO control input having a sensitivity of about 2 MHz/V, but otherwise it is surprisingly stable and well-behaved. The 50 MHz BPF cleaned up some harmonic mixing that was noticeable beyond 25 MHz, as did the VCO LPF. Without a real SA it is hard to test the device further, and largely pointless until it is fleshed out with the extra buffers and pads, and all nicely boxed up.

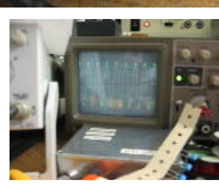
Sweeping Manually
(1.598 Mbytes)

As a useful device the main thing it is missing at the moment is the ramp generator control system. I intend to build it last though, as it is a relatively straight forward circuit using some op-amps. Presently a 100 k pot is providing tuning. The RF parts present more of a challenge, especially the levelling loop, I've never designed a servo-loop from scratch before but I imagine a primitive 1st order one will be fine?



Development work at the moment is concentrated on making the variable gain amplifier for the levelling loop. I've prototyped a low-distortion BJT/JFET cascode VGA that looks quite promising, but it has virtually no gain when setup to terminate the input at a reasonable return loss. I need to follow this with a feedback amplifier or two capable of delivering at least 10 dBm, preferably more. It would be nice to have a few volts RF into 50 Ohms to play with, say 15-20 dBm.





VGA Demo
(2.166 Mbytes)

The directional coupler might be replaced with just a simple moderate-impedance diode level detector in this initial HF instrument. This should offer a stable-enough level for sweeping antennas, filters, etc. The VCO output offers the possibility of using common sweep-circuitry in a HF spectrum analyser, a 50 MHz LC filter and downmixer + xtal filtered IF could be added externally, or even using some of the modules of the sweep generator itself. A log-detector would complete the primitive but useful SA.

8 comments.

Attachments

title	type	size
HF Sweep-Generator Block Diagram Source	application/postscript	14.497 kbytes

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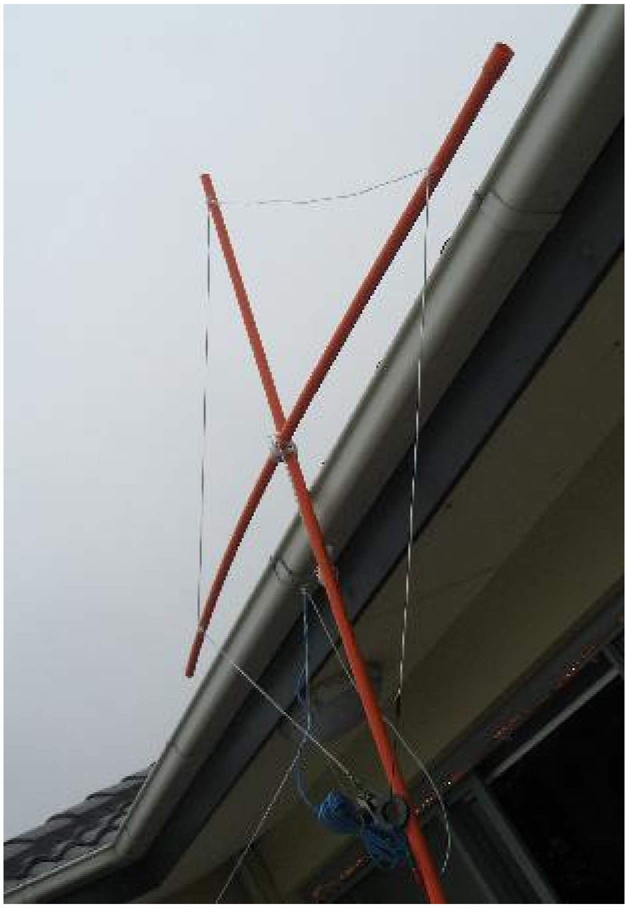
HF Receiving Loop

2007-12-16



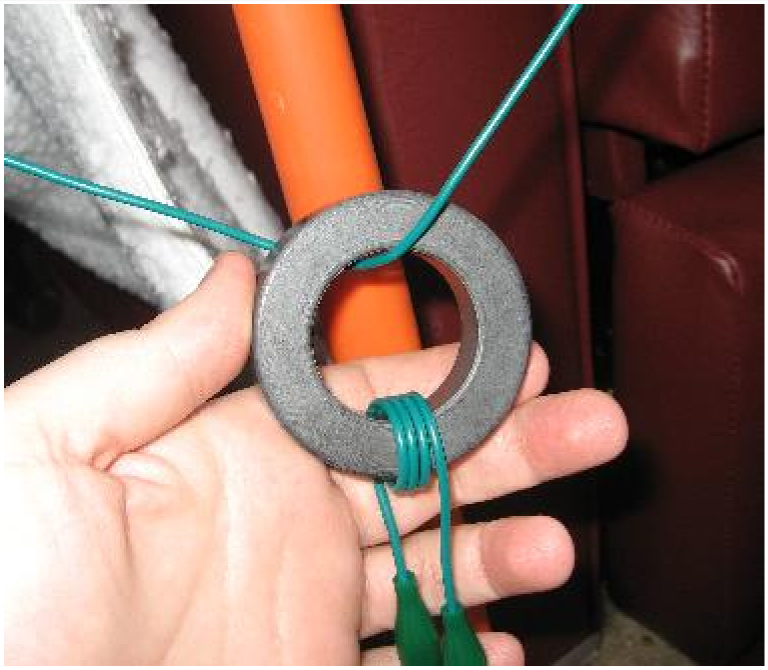
This experiment was inspired by Peter VK2TPM's receiving loop experiments for 80 metres. I saw his blog post last night and noted that his resonant frequencies looked a bit high, so I emailed him off my back-of-the-envelope calculations for what I figured he should be seeing. This morning I decided to check my own math by building a loop myself.

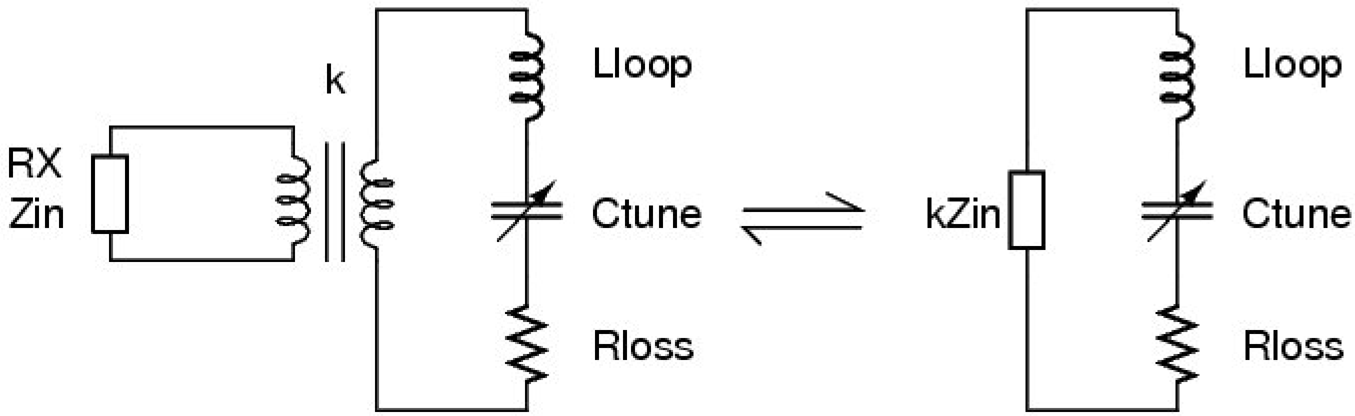
My loop is a bit smaller than Peter's, a single turn, the circumference is 4 metres + a little for the aligator clip lead, made from medium gauge mains lamp cord ("zipcord" for the yanks). The frame is just two pieces of 25 mm electrical conduit, lashed together with some sash cord. The winding simply taped in place for this quick experiment.

The "ring conductor" inductance formula suggests an inductance on the order of 6.4 uH, maybe a little more because of the relatively thin gauge of the wire. Direct measurements of the inductance at low frequencies using my larger-value inductance meter showed a similar order of magnitude, but the meter has limited resolution, at such values.

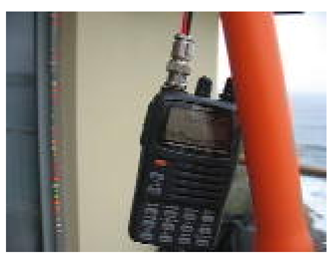
To get more accurate measurements I resonated the winding with my C Jig and coupled the loop into my VR-500 receiver with a large ferrite ring and some alligator clip leads. This allows detecting resonance at any frequency the receiver covers by just tuning the capacitance for maximum noise. In the local RF environment (lots of computers and telecommunications gear) there is plenty of noise for this kind of test, but even in the middle of no-where there should be a very discernible noise peak at resonance.

The receiver side of the coupling loop has too few turns I believe. The transformer reflects the receiver input impedance as a transformed value in series with the LC resonant circuit, degrading its Q. The LCR circuit so formed would be optimised by reducing the R (loss plus transformed loading) as much as possible, so the transformer ratio should be large to make the inserted series impedance very small (c.f. typical RF ammeter construction). Alternatively you might couple across the LC circuit instead of in series with it, into a very high input impedance amplifier, like a JFET.





The Q-degrading is easily observed with the receiver, the loop is not near as sharp as I initially expected, but the simplicity of the feed works for the purposes of the experiment.



Low-Q Demonstration
(1.926 Mbytes)

Systematically measuring the capacitance needed to resonate the loop from 4-17 MHz showed an interesting pattern which I can't quite explain. The affective inductance of the loop appears to rise with frequency. Some rise is expected as the distributed capacitance of the loop becomes more significant at higher frequencies (becomes non-trivial compared to the tuning capacitance), but it does seem to take off a bit too fast above 13 MHz.

MHz	4	5	6	7	8	9	10	11	12	13	14	15	16	17
pF	>210	150	110	80	67	44	36	29	24	20	16	13	10	<10
uH	<7.5	6.8	6.4	6.5	5.9	7.1	7.0	7.2	7.3	7.5	8.0	8.7	9.9	>8.8

Note that the numbers at each end are bounds because of the limits of the C Jig, and the outlier at 8 MHz is

scales), but the numbers do show a 6-7 uH inductance which is roughly consistent with the initial inductance estimate. Unfortunately the loop is too big to fit in the lab and measure with my full range of test gear, but from a purely empirical point of view the loop works fine, and the calculations give you figures in the right ballpark.

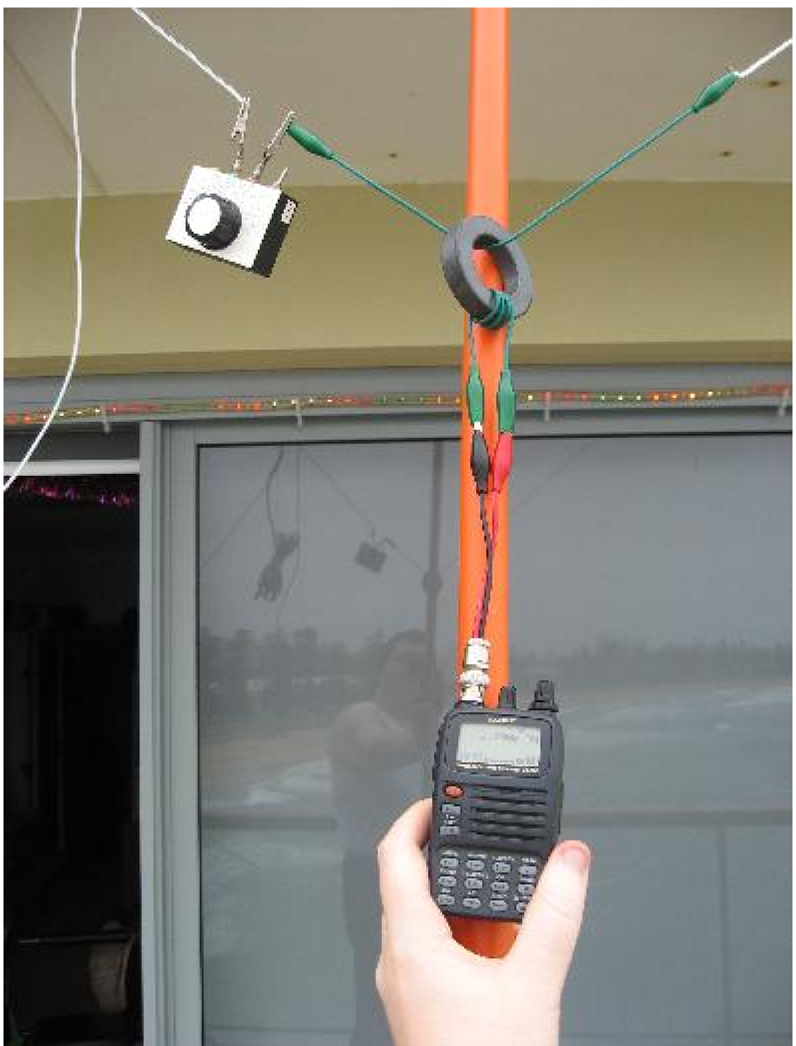
Still, I was curious just what was going on... At first I thought the receiver input impedance was being reflected into the loop circuit through the transformer (or was so high the transformer primary reactance was being seen directly, 1 fully-coupled turn on a FT240-43 core is about 1 uH and the affective coupling would rise with frequency). I also suspected the ferrite material itself may have been causing the effect, but some checking with the tone dip meter showed consistent results without the coupling transformer in place. I started to doubt the calibration of my C Jig, but after testing that with fixed inductances back in the lab, it appears there is another effect at work. I'm at a bit of a loss, but it might be related to the skin effect, or I've underestimated the distributed capacitance significantly.

Dipping at 40 Metres
(517.605 kbytes)

Confirming Resonance by Dipping at 10 MHz
(4.950 Mbytes)

Rocking Across Resonance at 5 MHz
(1.010 Mbytes)

My capacitor wasn't large enough to take the loop down to 80 metres, at least not without adding more turns, but there is no reason why a similarly sized single turn loop couldn't be used on 80. The normal LC circuit calculator would give you the required capacitance.



 XHTML | CSS | CSS toggle

This experiment was quite a bit of fun on a rainy Sunday. Very educational, especially thinking about the transformer feed and how I might use it in a transmitting version. I think such an antenna with remote varicap tuning would be a good addition to the shack. I was doing some experiments with varicap tuning yesterday, while fiddling with a VCO circuit. Red LEDs are surprisingly good varicap diodes, but I have a few BB-series diodes for AM broadcast receiver use that should do the trick.

Leave a comment on this article.

Attachments

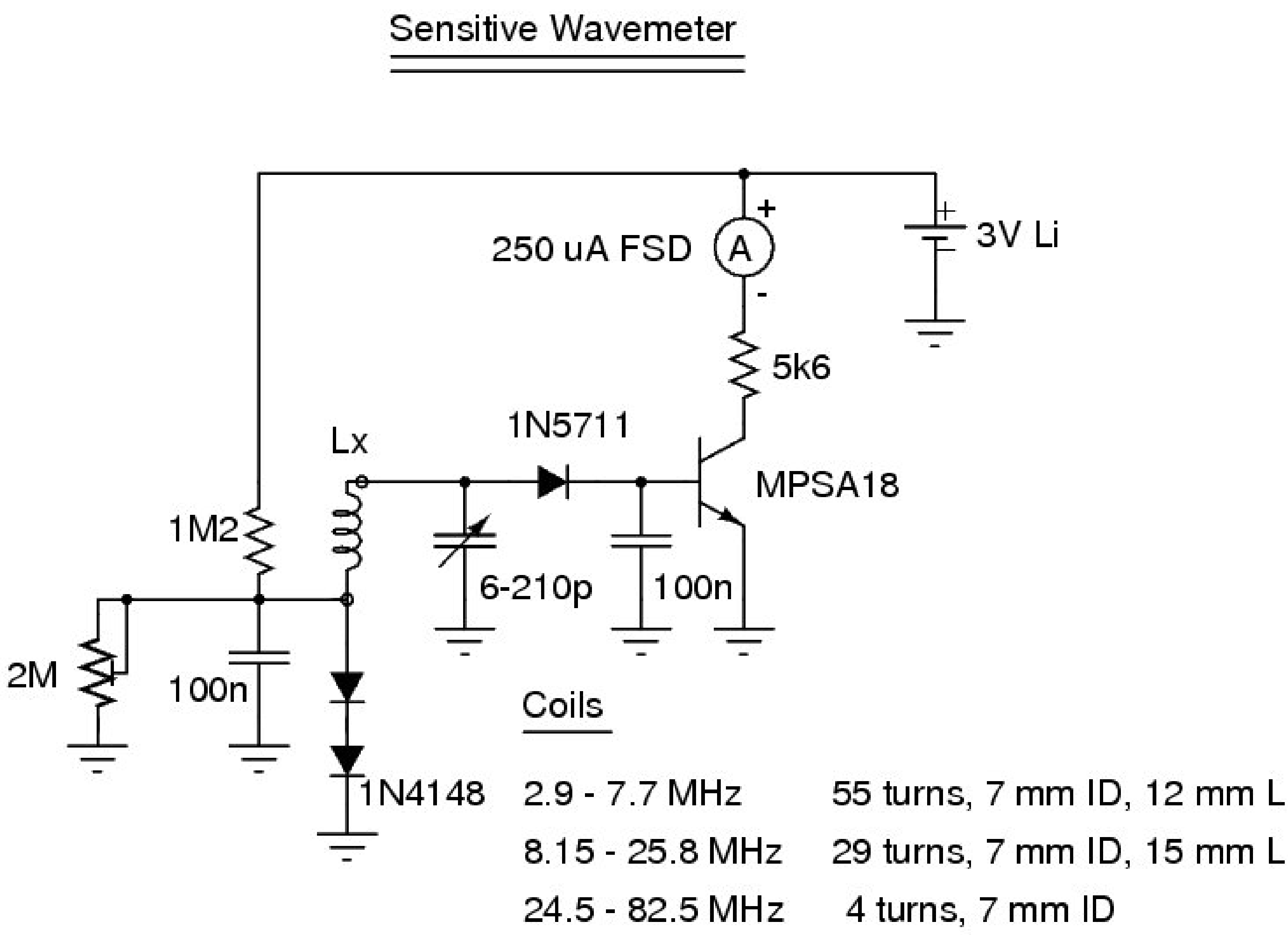
title	type	size
Feed Network Equivalent Circuit Source	application/postscript	12.026 kbytes

HF Wavemeter

2008-10-12

Why build a wavemeter in these days of frequency counters, CROs and spectrum analysers? Well it is a lot cheaper than a spectrum analyser, easier to build and can still tell you if you have significant harmonic energy in your signal or that you've tuned up to the right harmonic or mixing product. It also doubles as a field strength meter, RF current probe/sniffer, etc. It is a fun, if somewhat retro way of seeing what RF something is pumping out, be it your prototype on the bench, or a proximity smartcard security reader in the field.

The circuit is heavily inspired by Charles Wenzel's field strength meter. It uses a diode dropper arrangement to provide a stable forward bias for the 1N5711 detector. The pot shown in the circuit diagram was replaced in the practical circuit with a fixed resistor, but using the pot offers the ability to set the quiescent current. The exact amount is a trade off between sensitivity and moving the meter pointer too much. Mine sits on about "1" on the scale when a coil is plugged in.



The unit is constructed in a small jiffy-box, the 250 uA FSD VU meter taking most of the box volume. The meter comes from eBay seller KW Tubes, I bought a box of them. They are excellent, except they are glued shut so you can't (easily) change the scale, also the solder tags are nearly impossible to tin without filing them back to what appears to be a rather light on the copper brass. The power is supplied by a 3V lithium cell (CR2025). Current consumption is only about 10-15 uA when a coil is plugged in and no signal is being detected, it drops to less 2 uA when there is no coil plugged in, so no battery switch is required. The few components are mounted on a postage-stamp sized scrap of PCB using my usual technique. A polyvaricon tunes the coils and is fitted with a calibrated dial produced with the help of XYLs laminating machine. The PCB is mounted on the back of the polyvaricon internally with the common leg soldered directly to the board. The coil plug is an RCA, internally to which a short "transmission line" of magnet wire twisted pair

The coils are wound on 7 mm OD clear plastic soda straws (from Subway, they make great coil formers). Three coils are used to cover from 2.9 MHz to 82.5 MHz. There is a small gap near 8 MHz due to an excessive change in distributed capacitance when I potted the lowest frequency coil in wax. I had anticipated the problem and spread the turns out a little before potting, but the magnitude of the change exceeded the headroom I gave it. This could be easily corrected by removing a few turns.

The unit was calibrated using my signal generators and a frequency counter. Because of its fairly small size, the dial accuracy/detail isn't especially good, but for the purpose of checking harmonics, spurs and sniffing circuits this is of little consequence.

A better layout is recommended for extending the frequency coverage into higher VHF and UHF. Try forming the inductor as a thick loop that sticks out directly from the circuit board. Such a device could be custom built on a piece of PCB (and not much else except for the meter). In the opposite direction a larger capacitance cap would be useful, but there is nothing stopping MF coverage with the polyvaricon cap. In the picture the 4th coil actually plugged into the unit is a MF coil which covers down into the MW broadcast band (but the dial is not calibrated for it), it is about 150 turns over 10 mm on the 7 mm OD straws. You'd probably need at least two coils to cover all of MF nicely, and LF probably several more unless you get a better cap. A straight-line frequency cap (log cap) is strongly recommended for easiest use, unfortunately my stock of polyvaricons are straight-line capacitance (linear) so frequencies bunch towards the top-end. A larger knob or even a reduction drive improves the usability of the unit.

Leave a comment on this article.

Attachments

title	type	size
Wavemeter Circuit Source	application/postscript	14.762 kbytes

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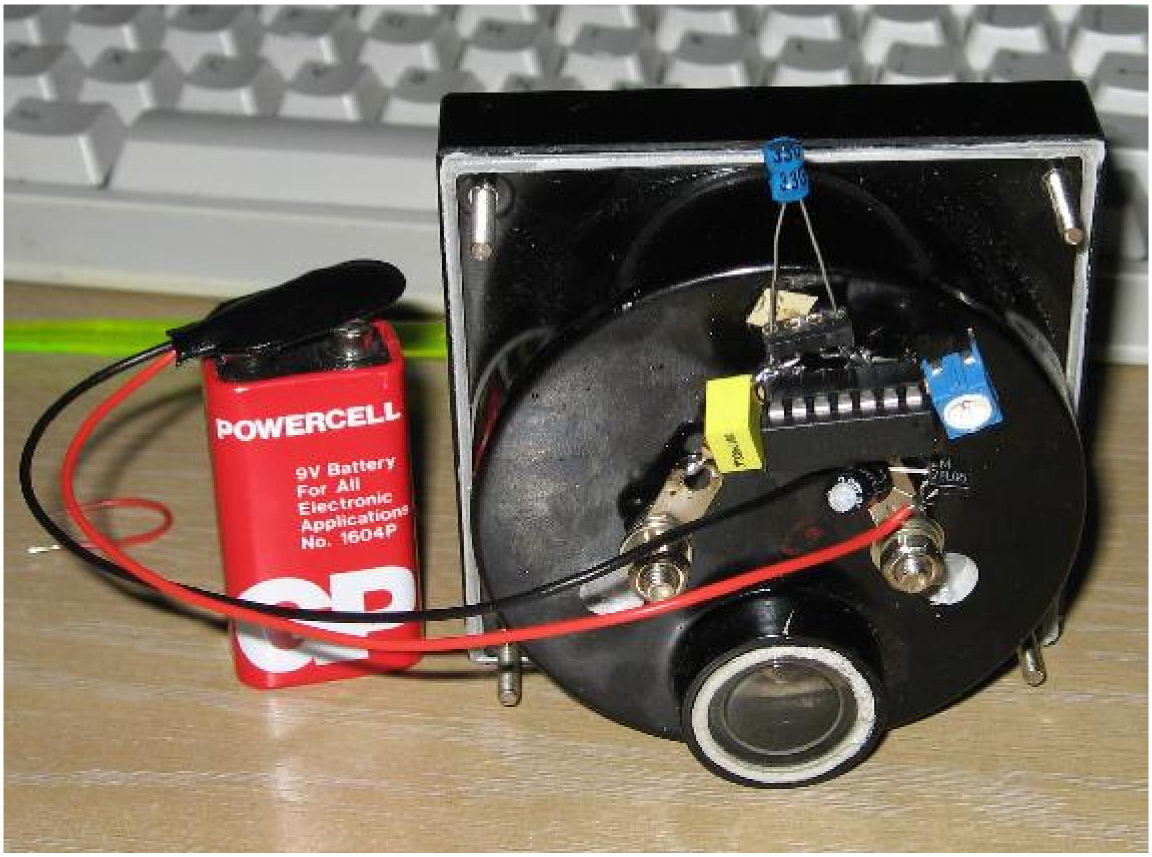
Inductance Meter

2006-09-03

Essentially identical to Dick's circuit, I built the unit point-to-point on an IC socket for the 74HC14 and a fragment of machined pin IC socket for the actual inductor.



Initially I used a DMM as the display device, but on a whim I tried hooking up a moving-coil meter. To my surprise, it actually worked just fine, 1K in series was sufficient to allow a useful calibration and didn't overload the drive capabilities of the last gate in the package.

I calibrated my unit for 0-100 uH, as this is the range I am generally most interested in, and it gives direct-readings on the uA scale of the meter. With the values as Dick specified, there is sufficient range to calibrate it from about 25 uH to 250 uH FSD.

Here is the unit measuring a 33 uH commercial RF choke.

XHTML | CSS | CSS toggle

The resolution of the analogue meter obviously limits its performance, but I generally use it to just ensure I am in the right ballpark while winding coils or picking from the junk box. More precise measurements I do with a resonance bridge.

4 comments.

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Inductor and Capacitor Measurement Fixture

2008-10-26

While I've built something similar in the past, this is a general purpose version for use with values of inductance and capacitance you tend to find around the bench. The circuit is almost exactly the Colpitts reference design in EMRFD (page 7.12, figure 7.24), except I changed a few of the component values a little.

I built the unit in a small diecast Aluminium box. Two polystyrene 1 nF and a NP0 12 pF capacitor were used for the oscillator. The calibration capacitor (~ 1 nF WIMA cap) is internal to the unit, with a switch used to activate it when needed. I measured it at 974 pF and have labelled the unit with this value. I only used 40 turns on a T68-2 core using 0.5 mm wire, but waxed them well to the core and ruggedly mounted the toroid in place. All the oscillator and buffer components were built point-to-point hanging off the banana jacks and switch posts. The resulting oscillator is extremely stable despite using a type-2 core, it sits for hours with < 1 Hz stability near 2.2 MHz.

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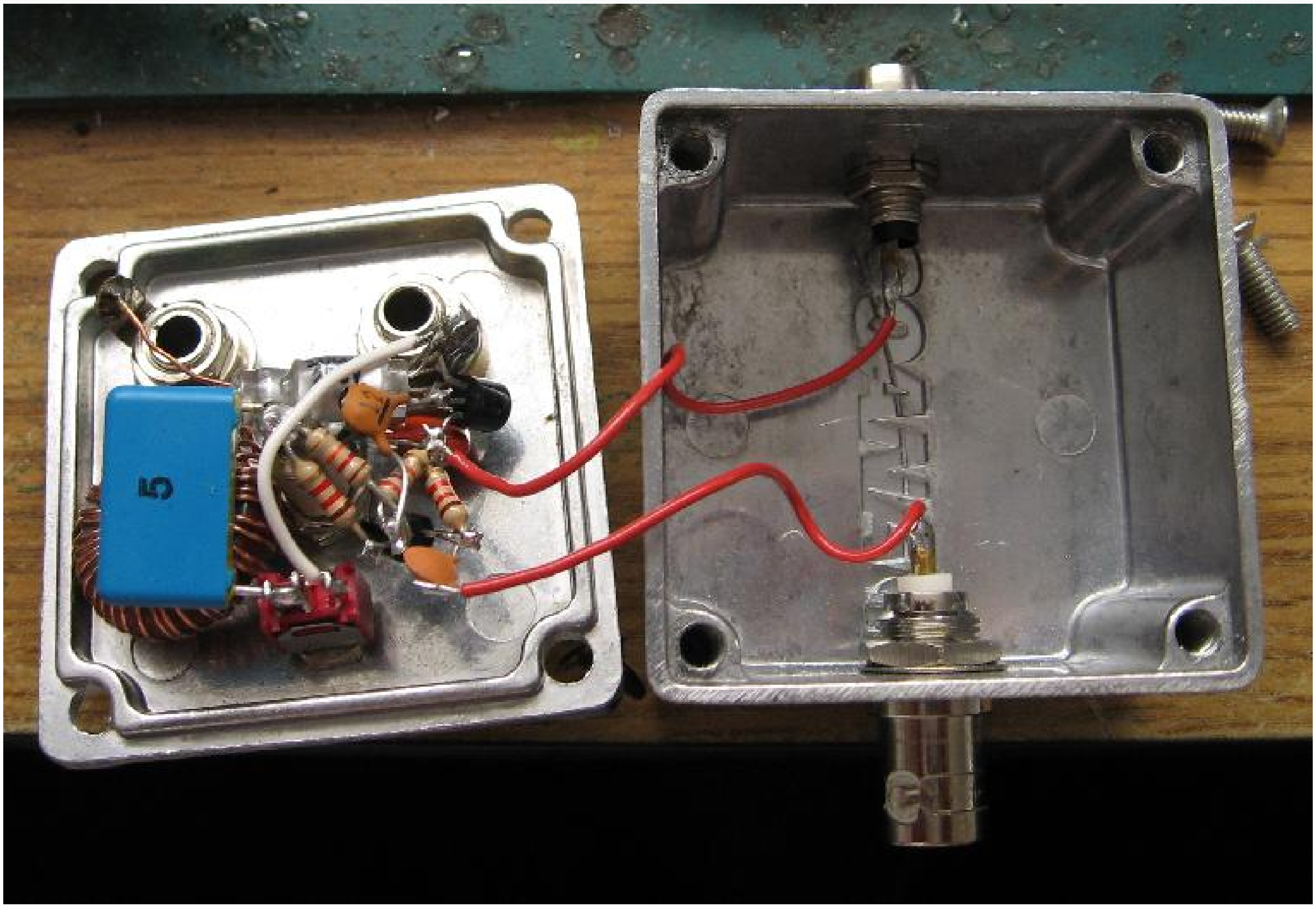


I've written a calculator to speed usage of the unit. As I've mentioned previously, this is a problem I've wrestled with and failed to solve in the past, but with some dedication I finally got the problem out. The need to measure inductor true-inductance and distributed capacitance for other projects took me in a direction that turned out to be a much better approach, the solution was actually quite trivial and should have been apparent much earlier. BTW: This method measures the apparent inductance, which can be in error if the coil has significant distributed capacitance. You can utilise the internal calibration capacitance along with the distributed capacitance calculator to approximate the coil true inductance.

My unit has a calibrated inductance of roughly 10.6 uH and a capacitance of 514 pF - this compares very well with what was measured of the components out of the circuit and the expected strays. Comparisons with inductors and capacitors measured via different means suggests good accuracy and repeatability. I currently use a short piece of 4 mm wire as a "zero" inductance reference. I can measure the difference in its inductance based on how far I push it into the unit - the measurement is consistent with the inductance of a straight piece of wire - I was pretty impressed by this level of resolution. I'll be building a matching test jig that plugs into the banana sockets and enables SMD and other small devices to be measured and allow nulling with extremely short lengths of thick wire. I expect I'll use it more to measure inductance than capacitance as I already have a digital meter for capacitance but this unit's resolution is superior. It would not be extremely difficult to write some MCU code to implement the calibration (reed relay maybe?) and metering giving a direct-reading meter - might have a go at that in the future (Yes I know you can buy a kit, but where is the fun in that).

Update

I've since replaced the WIMA calibration capacitor with a carefully measured parallel combination of several ceramic NP0 capacitors totalling 1017 pF (and relabelled the unit). This has improved the calibration accuracy of the unit slightly.

I also added a pi LPF choke to the DC power inlet as I noticed a ~3 Hz shift in frequency when I choked the DC power lead externally with a ferrite core and could detect a small amount of RF floating on it with my wavemeter. With the internal filtering this is no longer apparent. (The filter is simply a few turns on a ferrite bead with 100 nF caps either side of it to the lug of the RCA plug.) The DC voltage from my bench PSU is stable enough, but an internal regulator might be advisable if you are going to make lengthy measurements following a single calibration from a battery supply. The pushing from the supply voltage isn't huge and would probably be lost in the experimental error for most measurements however.

4 comments.

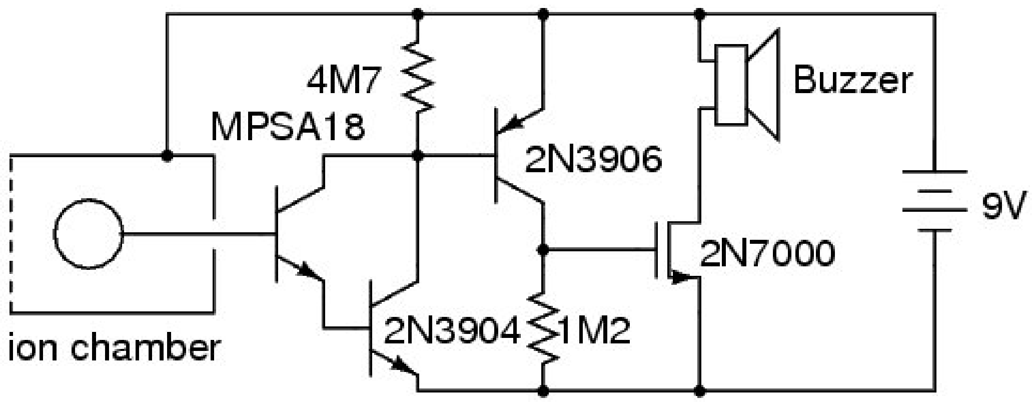
Ionisation Chamber Radiation Detector

2009-04-18

This is something I've been meaning to try for quite a while. Radioactivity has become a recent area of study, so this unit was thrown together. I half expected it not to work, back of the envelope calculations suggested I'd need a very large number of ions produced per second to produce the base current required... but it works quite well.

The circuit is basically Charles Wenzel's nuclear war detector. I didn't have Darlington devices in a single package, so I just used discrete transistors to implement the NPN pair. I used an MPSA18 for the device connected directly to the chamber and generic transistors for everything else. The "switching" device for the piezo buzzer is a 2N7000. The chamber is an eclipse mint tin, the collection electrode is a circle of tinned copper wire insulated from the chamber wall with a glass bead. The connection is made to the MPSA18 base in mid air.

Toy Ion Chamber Radiation Detector



As radiation detectors go, it is insanely insensitive. If this thing ever goes of when you aren't provoking it artificially then you are in rather serious trouble. The 37 kBq Americium 241 source I extracted from a smoke detector will activate it from about 1" if you leave the lid of the tin open to let the Alpha particles in. Alphas are very effective at generating ions. As a comparison, at the same distance from my Geiger counter's Mylar window I only get about 180 CPM (and about 22 kCPM point-blank).

Introduction and Americium Source
(7.022 Mbytes)

It is also sensitive to ions produced by combustion. Lighting a butane torch or a match near the chamber will trigger the alarm. You can also blow ions into the chamber from a gas flame or near the Americium source with your breath or by wafting, which will also trigger the detector. Naturally touching the circuit high-Z points will also set it off. Putting the Americium source right up to the transistors or heating them with a hot-air gun or contact with the soldering iron will also cause an indication.

Combustion Ion Sensitivity
(4.926 Mbytes)

The battery is fairly flat (measures 6.8 volts) and came from smoke detector that the Am-241 source was removed from. The circuit performs a little better with a fresh battery, but the main improvement is the loudness of the piezo and speed of recovery after radiation/leakage is removed, not its absolute sensitivity.

I was surprised I could get away with building the circuit as unshielded as it is. I suspect not being mains powered and being fairly compact helps. You can hear a little mains interference on the 'edges' of its turn on and off points, where the MOSFET is in its linear region and amplifies the noise seen across its base resistor. It is quite mild however and needs careful modulation of the alpha flux to maintain it outside of saturation or cut-off.

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Electrical Noise Sensitivity
(4.990 Mbytes)

All in all, it is a pretty cool toy. Quite amazing really that conventional transistors have sufficiently low leakages to make this practical. I want to build a real ion chamber now! I'm having trouble finding the high-value resistors required. I did find 1 GΩ resistors at Farnell for some insane price and have ordered a pair so I can build a device capable of measuring larger resistances - hopefully I can build my own 100 GΩ - 10 TΩ resistors.

5 comments.

Attachments

title	type	size
Toy Ion Chamber Circuit Source	application/postscript	12.278 kbytes

IR Remote Control Modem

2000-03-24

Goals

The general goal of the project was to develop a universal IR remote control interface for my PC. It was to be able to transmit and receive IR signals from a range of consumer electronics IR remote units.

Design

The unit had to be low cost, easy to build, and fairly easy to write a driver for. To these ends I chose a simple parallel port interface that I could talk to by bit-banging, and listen from using interrupts.

Not the most efficient design, but simple to implement, and very low cost. The transmit circuit is a simple single transistor buffer driving two IR LEDs in the collector. The receive circuit is a single buffer/inverter transistor stage driven from an integrated 3 terminal IR demodulator chip.

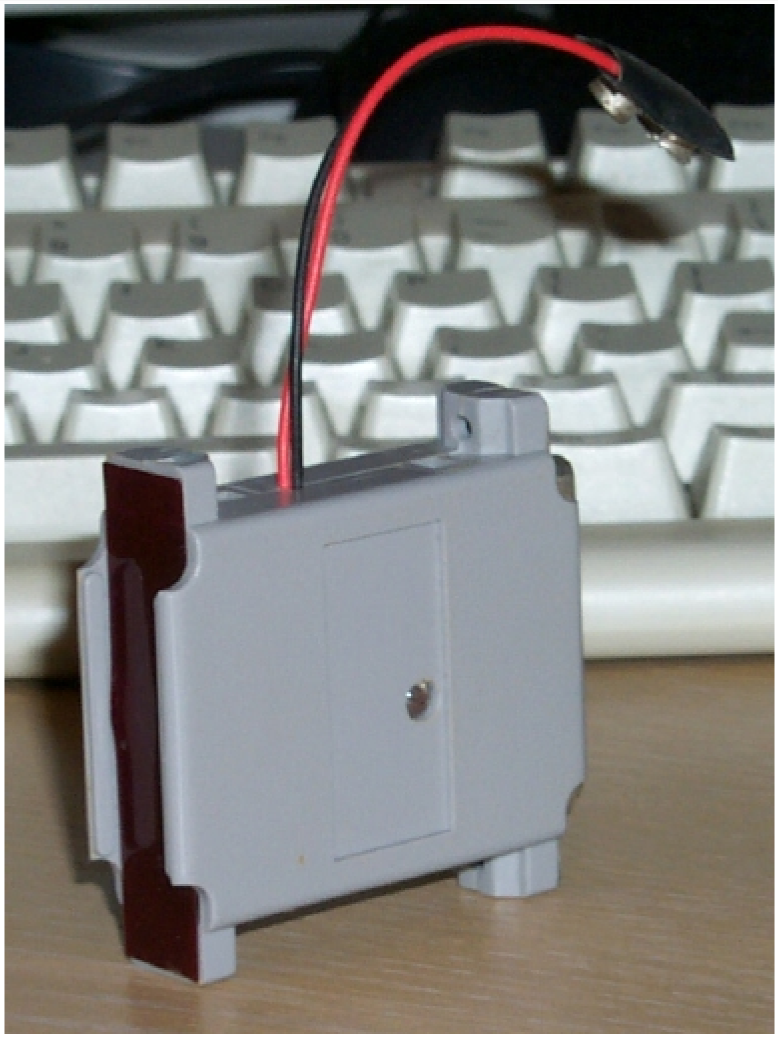
The unit case is a D-25 data cable gender changer hood. A small piece of dark red plastic from a scrapped alarm clock makes a reasonable IR filter which closes one end. A standard 25 pin female data socket closes the other. A single high brightness red LED services as an indicator for RX, (and TX due to reflected signal being demodulated). A 9v (216) battery supplies power for the unit.

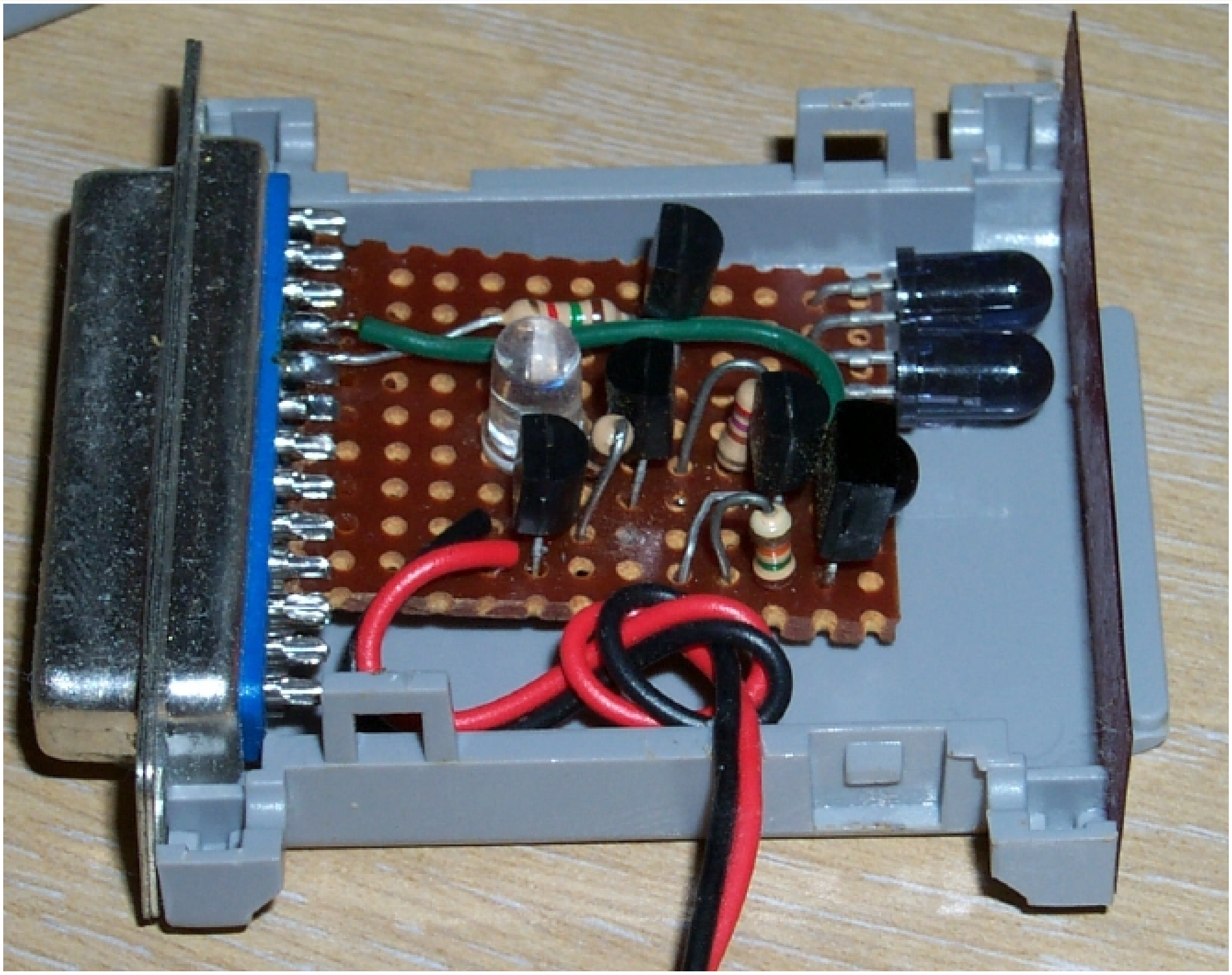
Logic interface is achieved by taking the MSB of the data lines (pin 9) as the TX signal, and feeding the demodulated RX signal into the ACK pin (pin 10)

The most expensive part of the device was the IR receiver chip. At almost $6 (Aus) it was about 40% of the unit cost. The IR diodes where about $2 each, the other assorted bits and pieces were of negligible cost. All materials where purchased at Jaycar Electronics.

Implementation

After about 2 hours with a soldering iron and side cutters I arrived at this unit. Simple and neat, except for the 9v battery snap.





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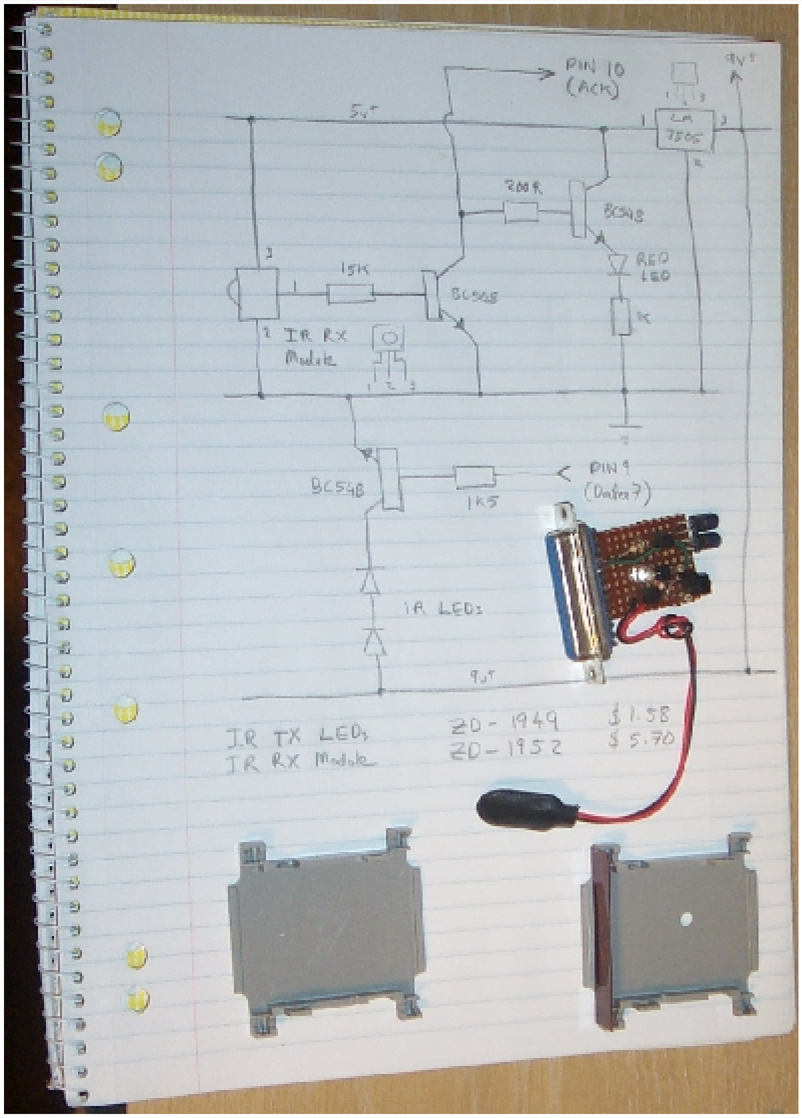


Talking To It

A simple Linux char device driver was written to talk to the device. It implements:

- open()
- read()
- write()
- select()/poll()
- close()

Honours O_NONBLOCK, is fully re-entrant, concurrent read() safe, and serializes write()s. It should compile on linux 1.2.13, 2.0.3x and 2.2.1x, and most likely will work on later kernels too, perhaps with some modification.

The User/Kernel Protocol

read() returns the timing, via do_gettimeofday(), of the rising edge of the demodulated IR signal. While this is not all the information in the signal, it is enough to decode all common IR signals.

write() is expected to *atomically* send a single integer (the IR carrier period in microseconds) followed by signal timing values in the form of pairs of integers; microseconds 'on' then microseconds 'off'. None of the integers passed may be zero (1 will do for the last 'off' time), for obvious reasons there is a limit on the maximum delay that will be honoured. Separation of the integers is via whitespace.

Userspace Magic

I find awk such a nice tool for quick hacks that I wrote some of the early tools to play with the modem's RX functions using it. Within a few hours I had worked out RECS-80 remotes, and the Foxtel (ST-100 cable decoder) box remote protocol.

Shortly after, I wrote a simple TX script that could change channels on the cable receiver, and later, tell my VCR to play, stop rewind, etc, basically anything I could do with the remotes.

Next I started on coding a proper C client for the device. One generic enough to send arbitrary IR signals, but with a sensible decoding chain that allows multiple plug-in protocol modules. This is where the project is currently up to. The TX hardware is used much more than the RX hardware, which sees use mainly for decoding new remotes.

The code is here: irctrl.tar.gz

Future Plans

The under utilized RX side of the device might be nice to work into a CD or MP3 player interface, or perhaps my TV card. Using a generic remote, like the one that came with the TV card, which features many buttons for TV/Stereo/VCR control, it would be possible to map many functions for remote control. (probably only useful if you are distant from your computer while enjoying its multimedia output. I guess some people will want to control their house with it :)

IR identification tags, through PAM modules, might be something fun to play with. Walk up to a workstation and it logs into your customized desktop.

open(), select(), and close() work as expected.

1 comment.

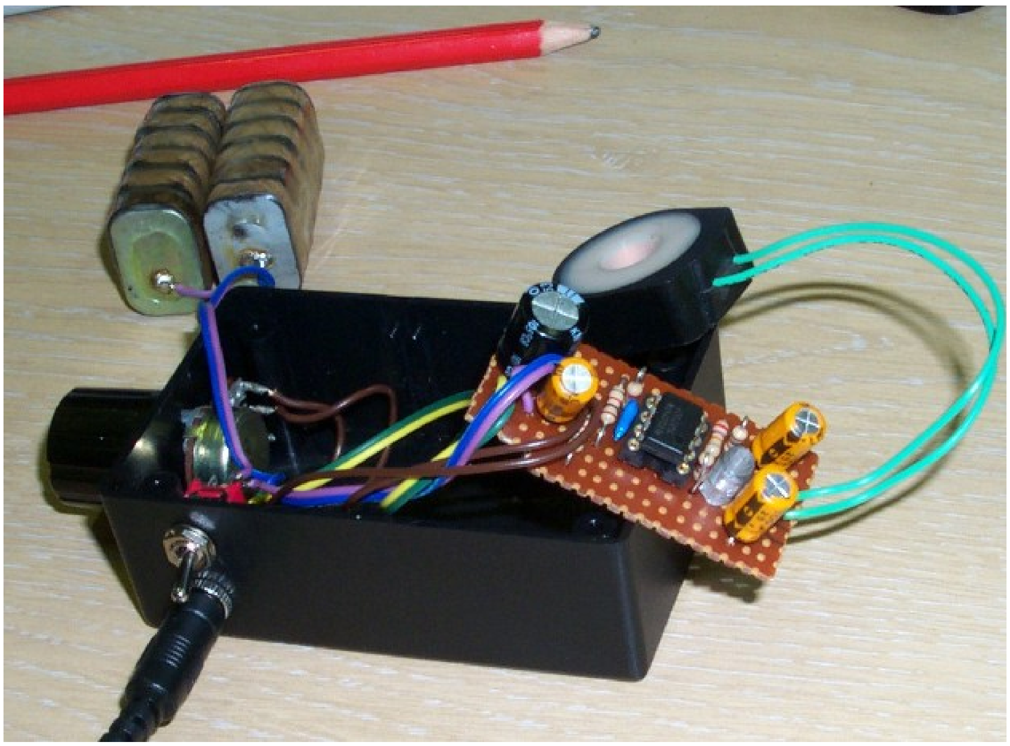
Mains Hum Survey Probe

2003-04-06

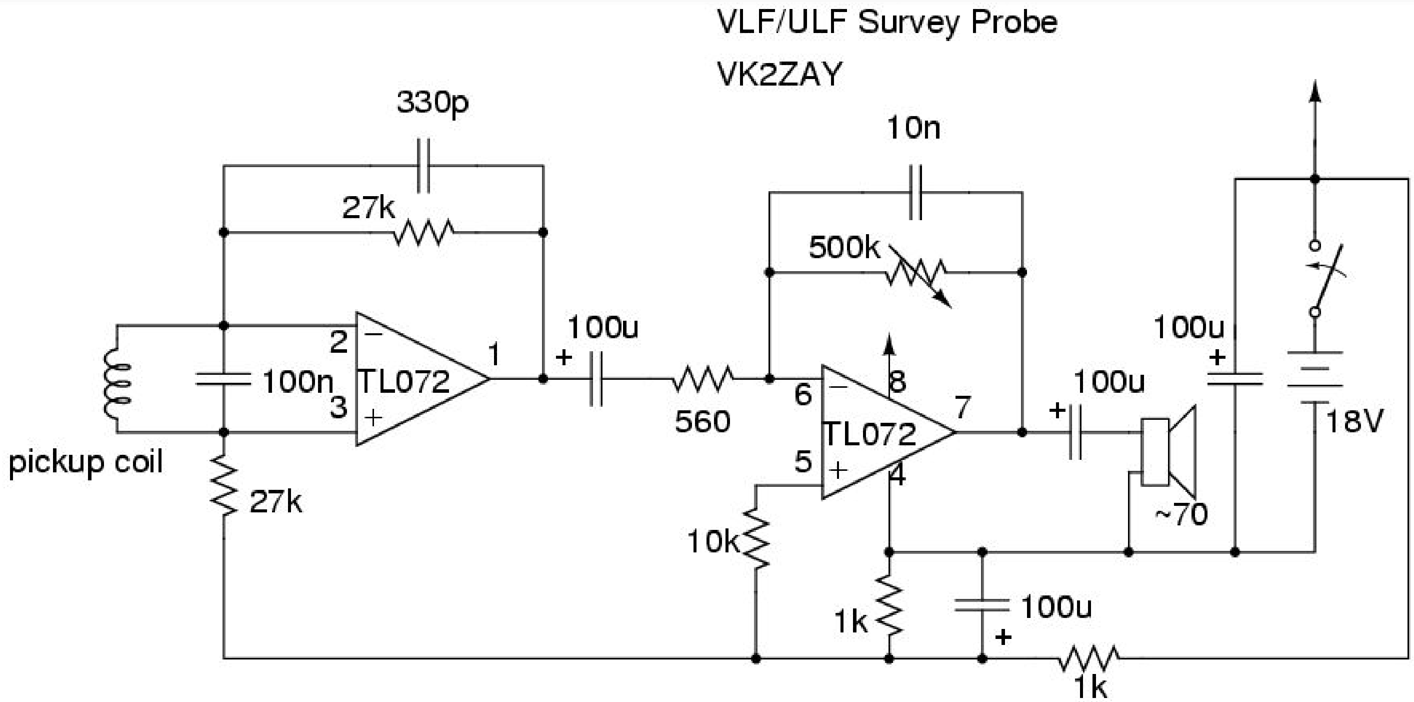
I've been working on VLF/ULF reception recently. In order to get a feel for the local mains noise I pieced together a simple opamp transimpedance loop preamp. With only a surplus solenoid coil for the transducer and moderate gain I got a huge signal out of the preamp, almost 500mV pk-pk. Clearly I'll need to go somewhere more electrically quiet for my VLF/ULF hunting.

I figured I may as well build the preamp into a portable unit so I could scout out quiet areas in the local region, hoping not to have to go too far into the bush to get away from the BUZZZZ!

I wanted to retain the TL702 opamp from the breadboard circuit for its fairly good noise factor. No where near as good as I'll need in the future full scale loop preamp, but I wanted to keep the noise low enough that when the mains garbage gets weak the circuit won't deafen me with hiss as I rack up the gain. This requires running the circuit off at least 10V. As hard as I tried, I just couldn't get the circuit to behave properly of 9V (especially as I am abusing the output with such a low impedance load, direct into a pair of 70 Ohm stereo headphones.) I settled with using 18V from a pair of 9V batteries. If I knew that voltage swing would be a problem in the first place I would have used the pair of 9Vs for a dual rail supply in a more conventional manner.



Fortunately the whole assembly fitted snugly inside the smallest Jaycar zippy box. At least once I skinned the batteries and soldered direct to their plates! The board was cut to mate neatly with the PCB slots in the box walls, the pickup coil nicely friction fitting between the chip at the end of the box. Just enough room was left once the middle of the box was consumed by the batteries to fix the gain pot, power switch, and 3.5mm stereo jack. Sometimes Murphy smiles on you and things come together perfectly.



The circuit is a fairly conventional frequency limited transimpedance amp of fixed gain, largely determined by the DC resistance of the pick-up coil. The other amp in the 8 pin package is used to provide a headphone acceptable power output, its gain is controlled by varying its feedback resistance to provide volume control and offer large dynamic range. I experimented with DC coupling of the two stages, but the untrimmed offset voltage of the preamp swings the output into saturation at any reasonable gain. This is only for aural use anyway so response below 20Hz is not required, still a largish 100uF coupling capacitor was used to get a good corner frequency (and I had a large packet of them sitting on the bench).

It takes a truly enormous signal to drive the preamp into clipping. Such signal levels would not be seen except perhaps when the device is used to locate mains wiring inside walls, or is accidentally turned on within a few inches of a computer monitor. I used carbon resistors, which was a mistake, noise wise, but the result seems fine, the transducer is too small physically to pick up signals of the kind that would require excellent noise levels.

I used a transimpedance preamp because I am working with magnetic signals here. When I think magnetic, I think current. Unlike electric fields where potential is the thing you want to amplify, magnetism is all about moving charge. It is easier to get the current gain with the virtual earth/short of the opamp input to satisfy the inductive transducer than it would be to get the massive input impedance for a capacitive probe of similar dimensions. I guess I could have built a FET input device with a small capacitive plate or whip, but the magnetic transducer has an excellent null which is good for locating noise sources, while the vanishing short monopole is almost isotropic.

It is fun to go for a walk with the unit. Many man-made things produce near field magnetic radiation that this device picks up easily. It displays the awesome penetrating power of a magnetic field, AC hum is easily detected through inch thick slabs of iron. My mobile phone makes an almost melodic series of pocs and chirps as it goes about its maintenance cycle. Computer monitors make grating tones for many metres. Inside a car the alternator whine and ignition noise is unstoppable. Power cables inside walls are easily located, and can be centred quite accurately because of the deep null pointing out the top-center of the unit. It is almost impossible to quiet the din however, so far I have never been in a location quiet enough to not hear the familiar buzz (or soft hum is the mains is pure enough - e.g. miles from fluros).

With a larger coil a circuit not unlike this one would be suitable for VLF/ULF monitoring. When I find a quiet enough spot, the transimpedance topology will likely feature in my preamp for the big loop. A lower noise opamp would be preferable, probably a LM833 or better, and more pains would be taken with metal film resistors, DC offset, and MF/HF rejection. The virtual earth/short property of the opamp inputs tends to neutralize the winding capacitance (there is almost no voltage across them), at least as fast as the opamp's slew.

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Attachments

circuit postscript source	application/postscript	14.272 kbytes

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MFJ-269 Review

2008-12-20

After my review of my MFJ-207 Peter VK2TPM offered me his MFJ-269 to play with for comparison. Naturally I jumped at the chance. The MFJ-269 is the fully-featured descendent of the earlier and simpler antenna bridges like the MFJ-207. The manual can be found on MFJ's website.

The device is microprocessor based with an LCD interface and two main control buttons "Gate" and "Mode". There is also a Frequency band switch, a reduction geared tuning capacitor, power and UHF mode switches. Two analogue meters display SWR and impedance magnitude continuously, offering a trending display which is more user-friendly than the figures on the LCD display. In UHF mode there is a "bargraph" of sorts on the 2nd line of the LCD for trending SWR.

The unit tunes about 1.76 MHz to 172.7 MHz in six overlapping bands. There is also a "UHF" switch that triples the oscillator in the 114-170 band giving 415-470 MHz coverage the edges of which are enforced in software, the display telling you to increase or decrease frequency until within that band. UHF supports only loss and SWR features, not reactive measurements - likely because bridge performance issues at UHF would have required extensive calibrations to have any hope of accuracy.

The coaxial connector is a N-type and is surrounded by a generous rubber gasket. The frequency counter input is a BNC. The DC plug is a conventional unit, tip positive, I am unsure what internal over-voltage and polarity protection it has. There is a large grounding lug also provided.

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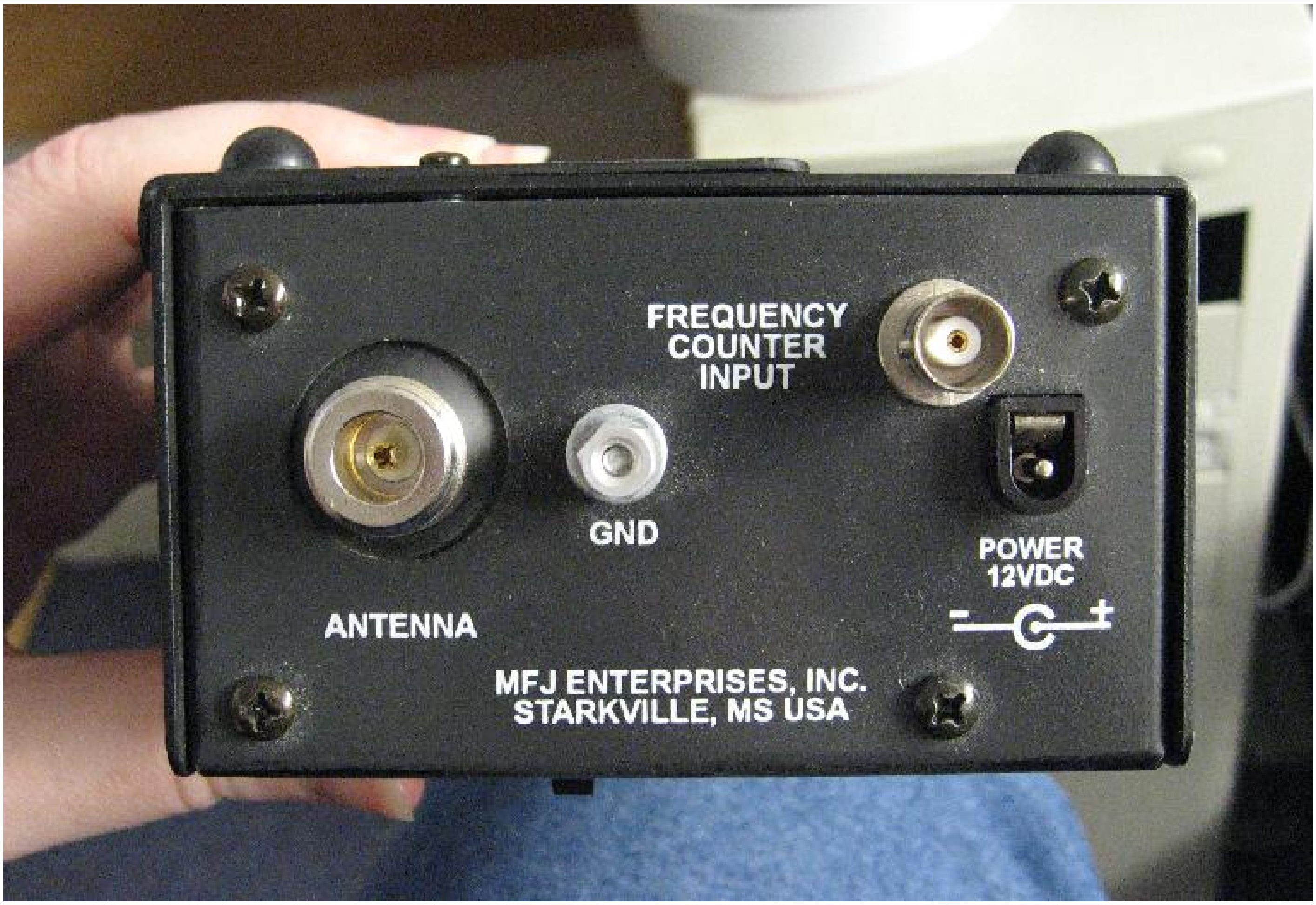


Features

There are 4 "Main" analysis features and 3 additional menus of Advanced ones. The advanced ones are mostly just different presentations of the same data from the bridge voltages (impedance in polar form, reflection coefficient, return loss, etc), but there is the option to select a different "Zo" for the calculations and also a two-frequency point semi-automatic calculating feature for line length, distance to fault, etc. The line length and fault distance calculations are pretty good, resolving several short (~2 metre) lines and offering compensation for velocity factor.

By pressing the "Mode" button you can cycle through the different modes, both main and advanced (once entered). Holding both the "Mode" and "Gate" buttons gives access to the advanced menus. The "Gate" button is used in frequency counting mode and as an enter-key of sorts in the calculating modes. Holding both buttons down on startup then alternatively pressing them as it boots enters the "Test" mode which gives a display of the raw ADC data for calibration of the unit with a set of calibrated dummy loads. The button mashing required to enter "Test" takes some practice, thankfully it isn't something you'd be doing often. The software version is displayed at boot, in this case 4.46, copyright 2004.

Impedance Analysis

The default "main" mode is the "Impedance R + X" mode and displays frequency, VSWR, and impedance as Resistive and Reactive magnitude (Rs +/- jXs) which update continuously as you tune around. The sign of the reactance is not resolved and displayed, which is pretty typical of the bridge system the device uses. The frequency counting is probably the "killer feature" of the device as well as the reactive magnitude display which allows searching for true resonances not just minimum reflection coefficient magnitude.

The impedance mode does seem to work pretty well, especially below 50 MHz, but is limited by the device's calibration accuracy. I am not very confident the unit I was playing with is calibrated properly, resistive magnitudes reads high, sometimes more than double - and above 300 Ohms resistive the reactive magnitude rises very quickly too, even with a "pure" resistance in the lowest frequency band. This and other behaviour I noticed suggests the "Vz" channel gain is a bit high. Upon checking the calibration pots under the battery holder I noticed that R72 was bottomed out, offering insufficient range to properly calibrate the unit as described in the calibration procedure. This is suggestive of mismatched or damaged diodes in the bridge or perhaps an incorrect resistor value or tolerance catastrophe. As the unit is not mine I didn't pull it apart to inspect the rest of the circuit and attempt to diagnose it further.

Coax Loss

The second "main" mode is "Coax Loss". It appears to simply display half the return loss measured by the bridge. When an unterminated coax line is attached the bridge sees the through-and-back (returned) loss of the line, which is twice the line loss for that particular length. Similarly you can attach attenuators and other lossy devices to the unit and measure their loss this way. The loss maximum appears to be 24 dB and is likely limited by the best bridge directivity over its frequency range (ie 48 dB, pretty good). As the unit is measuring with a 12 bit ADC a linear signal (not a log detected one) the dynamic range is pretty limited and the loss quantisation is fairly coarse. For "good" vrs "completely waterlogged" measurements of coax it is likely sufficient.

One annoying thing is the lack of auto-zeroing, this particular unit would always read about 0.9 - 1.6 dB return loss at HF. It would be nice to have software zeroing. In fact I can't see why the entire device could not have been designed to ship with a set of calibration loads and full software fine calibration. I do understand that some of the gain settings are quite critical, especially for reactance zeroing with the limited dynamic range offered by the 12 bit DACs fed by linear detectors. Still it would be nice to have "tare"-style zeroing for some measurements.

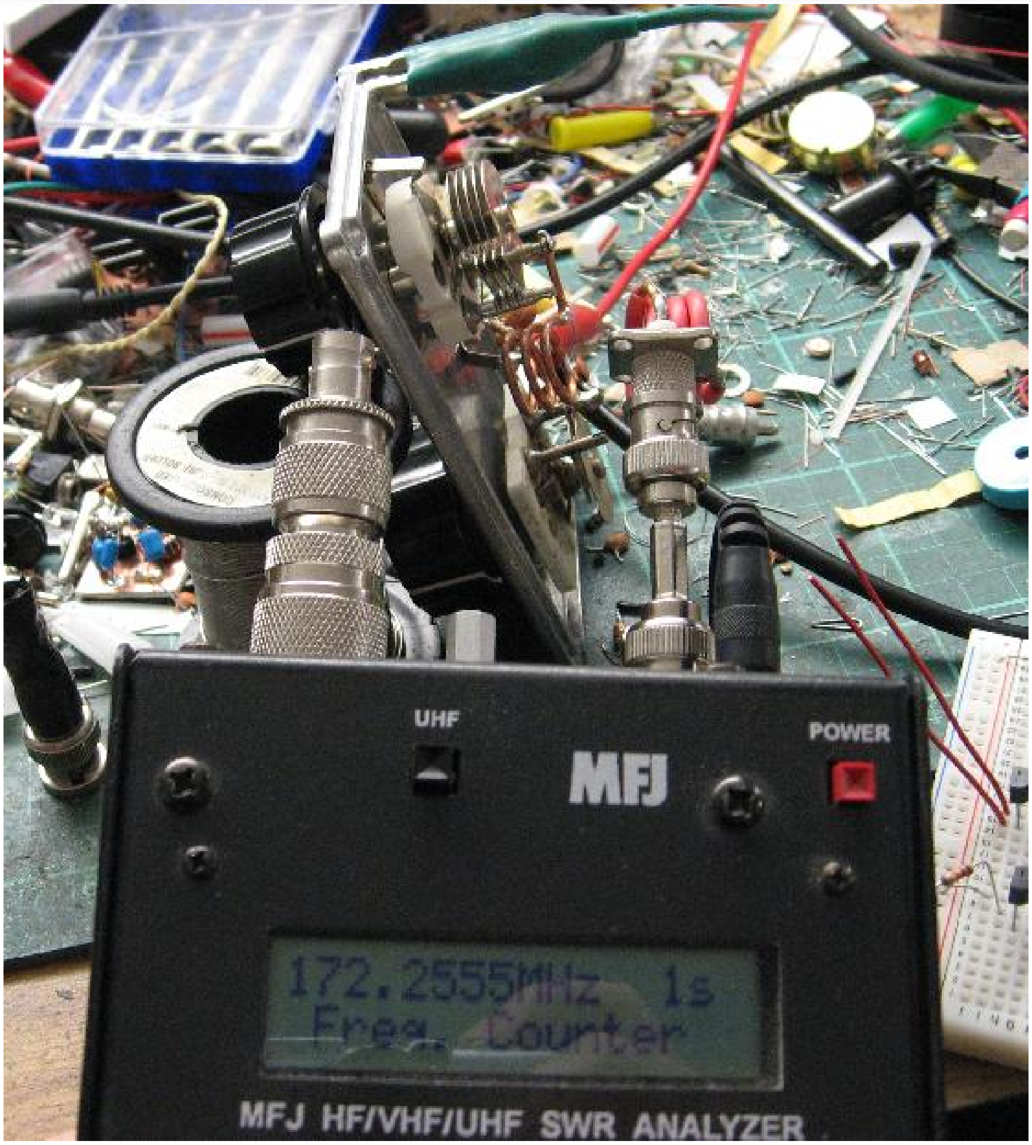
Capacitance and Inductance Measurement

The Capacitance and Inductance measurements simply compute the reactor value that matches the current reactive magnitude reading at the current frequency. It has no way of telling if the load is actually inductive or capacitive, and once outside the few ohms to 1.5 kohm range of reactance magnitude the software stops giving you a solution. This makes perfect sense, you just need to tune the VFO until the frequency offers a reactive magnitude in-range of the unit. The computed values are most accurate when the reactance magnitude is close to the bridge reference resistance (50 Ohms). This particular unit read high, about 19 pF high (about 6 pF of which was the test fixture) on average and again there is no way to null it. Inductance was probably worse but I didn't test it extensively, only a few trial inductances were compared to values measured by my LC tester. The LC measurement is nice to have, but I wouldn't trust it - in fact I'd go as far as to suggest using the frequency counter feature along with an external jig like the LC tester instead.

Correctly calibrated the general measurement method is probably fine and quite useful as it tells you the true impedance of the reactive component at radio frequencies (unfortunately only those that present a 7-1500 Ohm impedance). For testing a component for spurious resonances this is very useful, but in practice I couldn't seem to easily find misbehaviour in capacitors. Inductors on the other hand were fairly easily tested for self resonance, but being placed in the tester environment pulled their self-resonances quite a lot. Dipping them instead is probably more reliable.

Frequency Counting

The frequency counting feature works as advertised. It can accept signals up to 5 volts and has an high-impedance input. I could easily get a stable measurement with just a few turn coil plugged into the input using my dip meter as a signal source from several inches. The counter counts to beyond 170 MHz, I didn't test it higher. I assume the "UHF" feature actually counts the VHF generator and triples the value in software? I can't see a counting range spec in the manual. The gating works as expected, long gating times give more resolution figures. The reference seems stable and accurate enough for the resolution offered.



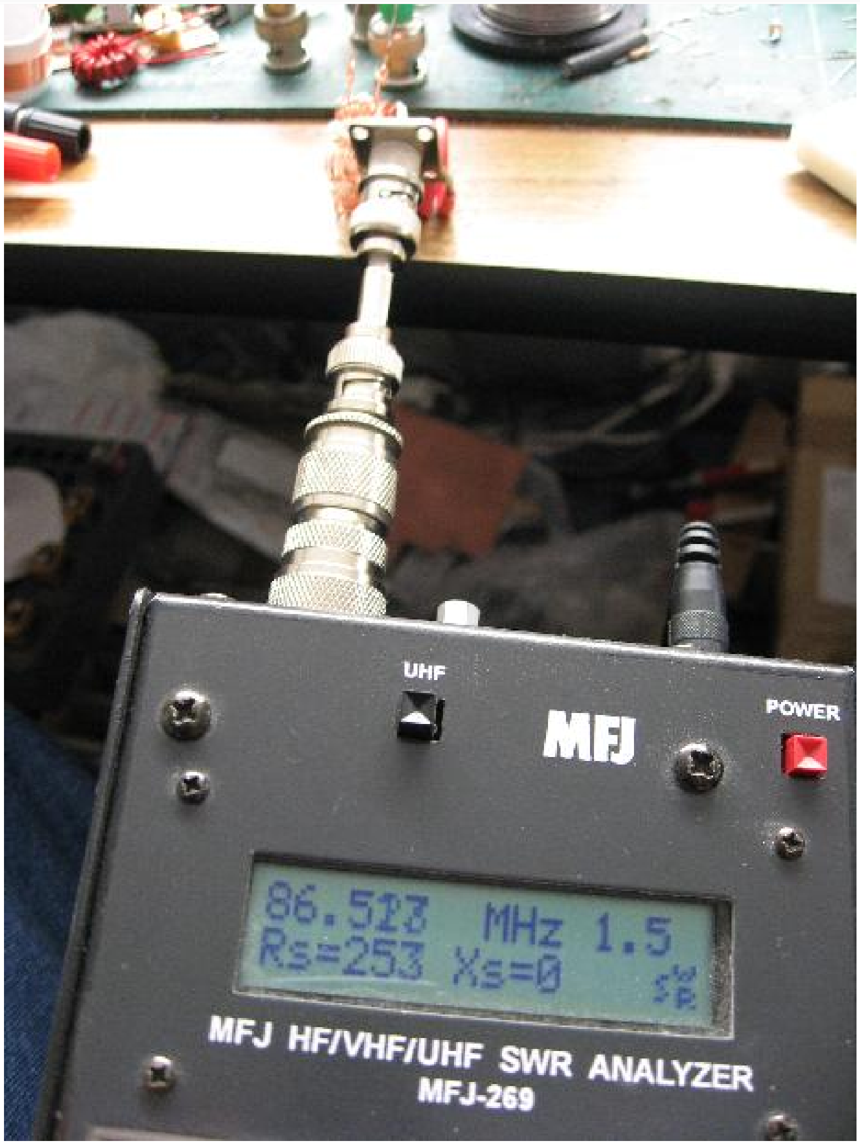
Advanced Features

Of the "Advanced" modes the stub length and resonance searching ones are probably the most useful. The stub length helpers are great for cutting matching and phasing stubs. Accuracy for 1/4 lines seems pretty good when compared to dipping a line with other instruments. It is unfortunate that the physical lengths are only given in feet. A metric physical measures software option would be nice, but considering this is a US product this is perhaps not surprising. The resonance searching mode makes the Impedance magnitude meter show Reactive magnitude while looking for a null. Oddly it does not use the LCD bargraph like SWR in UHF mode, instead showing Xs numerically.

The match efficiency mode is arguably the most useless feature. I'm not really sure what the point of it is. I guess there was extra room left in the MCU code space, so yet another "feature" was invented to fill it. Personally I'd prefer metric measures or software nulling instead.

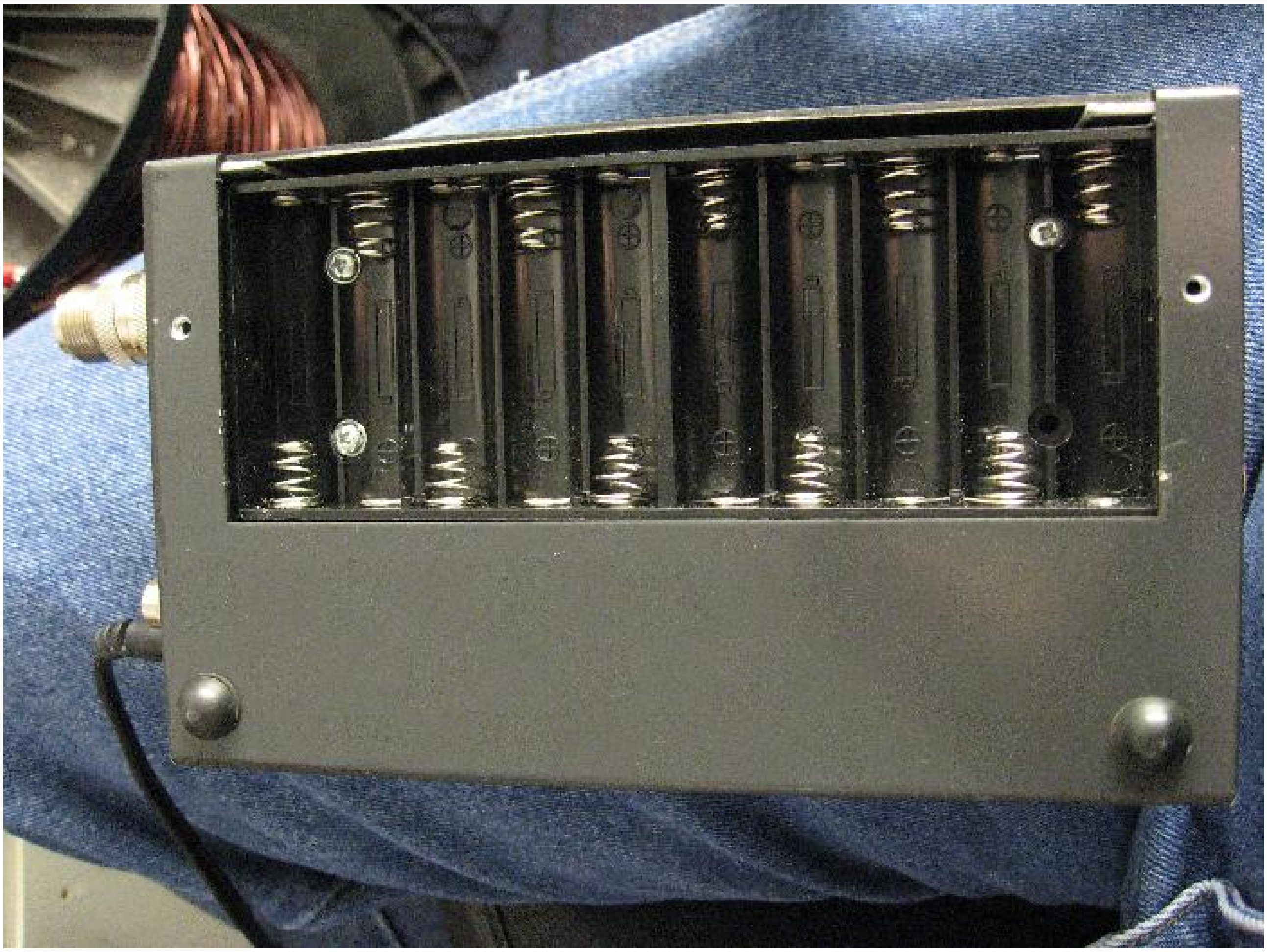
Use as a Dipper

I understand there is an optional dipper coil set for the MFJ-269? - I just plugged my few turns of wire on a BNC into it and tried it out on some inductor self-resonances. It works quite well on HF and VHF. I'm not too confident about it on UHF, but the UHF range is quite narrow which makes it fairly useless for dipping anyway.



Power Consumption

The device does guzzle power. On HF-VHF in the default mode it pulls 140-170 mA (rising with frequency). On UHF it pulls over 350 mA! In counter-only mode it still pulls 90 mA. The AA batteries won't last long, and it takes 10 of them. Unlike the MFJ-207 at least you only need to remove two short machine-threaded screws to access the batteries. The external power option is almost mandatory (use at least a 500 mA plug-pack), but it does offer the ability to charge rechargeable batteries inside the unit by changing a jumper on the PCB. I have no idea how well it manages them if you choose this option.



By default the unit enters a sleep mode to reduce power consumption after a period of inactivity. This would help extend battery life, but it still pulls more than 50 mA. The sleeping feature can also be disabled by holding down buttons while the unit is powered on and remains disabled until the power is cycled again, much like Test mode.

Comparisons to the MFJ-207

The 207 is very basic compared to the 269. The 269's frequency counting and reactive magnitude display are its best features. The 269 has none of the FMed oscillator problems of my particular 207 and has much improved buffering and harmonic distortion. There is a pot in the 269 for setting buffer bias up to minimise the harmonic energy. I didn't test it extensively, but there is a detailed procedure available using a coax stub instead of a spectrum analyser to ensure this is set correctly. Tests with narrow band antennas like my balcony HF vertical and bicycle loop antenna show it is very much improved over the 207. I can resolve the resonance of my balcony vertical on 80 metres with the 269 fairly easily where it is next to impossible with the 207. I even tried measuring a colourburst crystal with the 269. The xtal resonance is very steep and the analyser tries its best, but it is simply not sufficiently stable or well buffered enough to stay in the resonance. You can detect it and even get a fairly good idea of its frequency however, and see spurious resonances of the xtal as well.

The 269 covers part of VHF where the 207 stops just above 30 MHz - and the 269 also has the narrow UHF option. On UHF the 269 is essentially as limited as the 207 is on HF, measuring just return loss. I am highly suspicious of the UHF feature's accuracy and debate it actual usefulness for most HAMs.

Like the 207 the 269's SWR meter is largely just for trending. The calibration point is 2:1 (using a 100 Ohm load), above and below this the displayed figure is quite wrong. The LCD display however shows the correct figure, at least below about 5 - and of course if the unit is calibrated properly. (The impedance meter is a bit better, its calibration point is 50 Ohms using a flat load. Again the screen gives a more accurate reading.)

Summary

The good:

- Frequency display
- Reactance magnitude display
- Separate impedance and SWR analogue meters
- Mechanical reduction driven tuning capacitor
- Display options including RL and P
- Fairly compact unit, self contained

- Fairly stable and pure local oscillator
- Internal battery charging option

The bad:

- Large power consumption
- No nulling options (especially for L/C measurement)
- Imperial physical length measurements
- Analogue SWR meter scale calibration is poor
- Tendency to arrive broken or poorly calibrated

On the last point the evidence is only anecdotal... Well, the unit I played with has a poor calibration and Peter experienced a lot of problems with it himself. His is not an isolated experience if you search HAM forums.

Conclusion

The MFJ-269 seems to be designed quite well. I am sure with careful calibration it is capable of quite reasonable accuracy over HF and into VHF. I strongly suspect it would be quite difficult to design something more accurate without ending up building a true vector network analyser with log detectors and synthesised local oscillators. With recent advances in technology it might be possible to build such a device for about the same asking price, but I am sure the development costs would place its initial RRP closer to $1k, making the MFJ-296 look like quite a bargin.

Is the MFJ-269 overpriced? Well perhaps. Especially in the light of the horror stories out there about some HAMs experiences with the unit. How many of them are due to "operator error" is unknown, but MFJ is very well known for having quality control issues, so it is likely that many are real hardware problems. Fortunately there is also a great deal of support available for the unit, with MFJ sending part kits out to repair blow-up or factory-buggered units. By virtue of its ubiquity (and from the earlier 259 and 259B units) the HAM community has plenty of resources for fixing busted MFJ-269s.

Would I buy one? If it was < $300 AUD - yeah I would take the risk of getting a lemon. I would feel more comfortable if there was a circuit diagram in the manual, that way at least I could fix it easily enough. There are diagrams online that profess to be of the 269 or 259/259B, they seem pretty correct but I haven't extensively studied this loaner unit for comparison. There is a calibration procedure available, and one for the 259/259B as well from the original designer, but note that the 259 has 8-bit ADCs so the hex values displayed on the 269 and the pot numbers don't match this page - still it is a useful read and the document on the MFJ site seems to match the general guidelines when you convert to 12 bit numbers.

Unlike a VNA-solution the MFJ-269 isn't tied to a PC which is important for field work on antennas, but this is becoming less of a problem with USB-based VNAs that can run from a Netbook form-factor PC, perhaps it would be best to save the money and invest in a VNA as many of us already have a netbook PC, especially for use in the lab rather than just antenna work. Still, it would be nice to have it all in the one portable box like the MFJ-269.

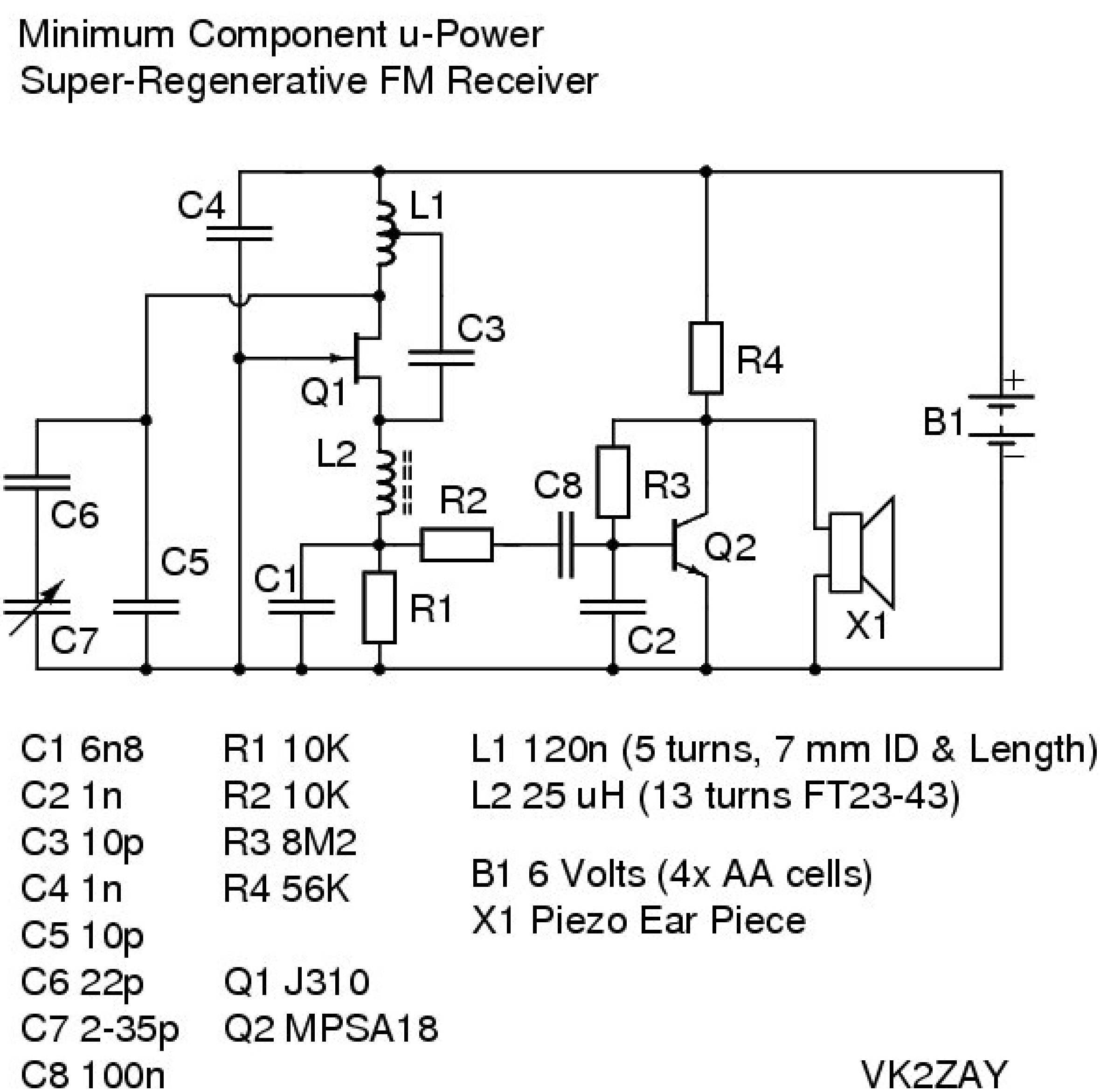
5 comments.

Micropower FM Broadcast Receiver

2007-09-08

It's been quite a while since I built a super-regenerative receiver for the FM broadcast band and I've been meaning to play with a different source feedback topology, so this little radio was thrown together on the Saturday of the APEC long weekend.

The topology is your classic grounded-gate FET VHF Hartley oscillator. The drain resonator inductance is centre-tapped with feedback to the source through a small capacitance. By tapping down towards the cold-end of the coil the feedback isn't as critical as your usual source-drain capacitor feedback and it tends to be far less difficult to get to work across a broad range of frequencies. The RFC to an RC source circuit to implement self-quenching is very traditional for super-regenerative detectors. The quench gets frequency-modulated somewhat by the drain current, so it varies with signal strength and the recovered modulation, this is typical for self-quenched circuits (simplicity has its price).

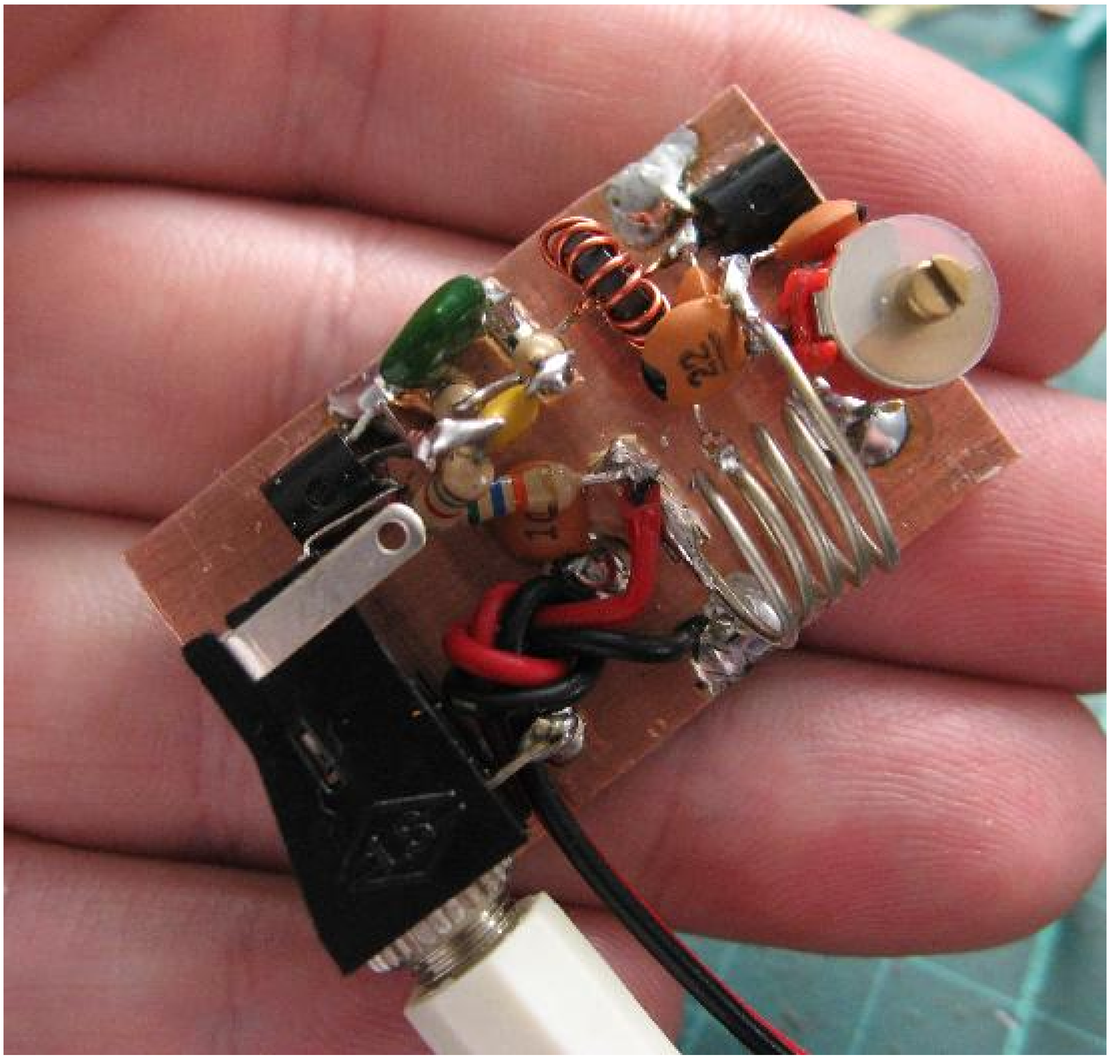


The detector alone provides sufficient audio to drive a crystal ear piece in a very quiet room, giving a true "single transistor" FM receiver. A largish resistor (~10 k) prevents the source circuit from seeing too much of the

range. Some additional audio volume can be achieved by redesigning the quench circuit to utilize the piezo capacitance directly, but the source resistance has to be dropped quite a lot to achieve a viable quench frequency and the gain in sensitivity isn't as fantastic as one might hope. Still, give it a try, a single active device FM radio, pulling < 100 uA is mighty impressive!

The detector can operate with the source resistance approaching 1 M, even at extremely feeble currents it is still very sensitive. Best over-all performance was achieved with 10 K and 6.8 nF in the source circuit.

I decided to add a stage of audio gain, retaining the use of a high impedance ear piece to keep the current consumption as small as possible. I picked a super-beta transistor, the MPSA18, for the audio amplifier, and used a simple self-bias topology. This was all to keep the total receiver current consumption very small and maximise the battery life. The audio quality is quite acceptable (the usual super-regen' slope-detection distortion and quench inter-modulation with stereo sub-carrier, etc). There is no volume control, the super-regenerative receiver has an AGC-like quality because of its physics. The audio power available is on the low side, it is for quiet environment listening only; not exactly library-quiet, but not the local pub on Friday evening either!



The complete receiver pulls around 500 uA from 6 volts. Four of your average bargain-store dry cells should run the receiver for at least a month continuously. Band-name alkaline cells might run it for a very long time indeed.

Tuning is achieved with a small alignment screwdriver, or similar insulated tool. The trimmer rotor is "grounded", but hand-capacitance is still slightly present because of the very high frequencies and gains involved (i.e. minor circuit layout strays).

Some effort was put into setting up the trimmer bandspread to cover the FM broadcast band (i.e. picking C5 and C6 to make C7 tune 88-108 MHz). I spent a lot of time doing the algebra to try to come up with a way to calculate the circuit stray capacitance and the actual tank inductance by trial frequency measurements with different fixed capacitances. The solution is truly horrible; involving finding a parabola that fits three points, which means solving a determinate of a 4x4 matrix equated to zero... I gave up after a few hours of wading through my sign and subscript mistakes, the whole experience leaving me feeling somewhat defeated!

I really wanted to achieve a result I could use to write a calculator, not unlike the VFO helper one which I did the

parameters just by measuring the frequency produced after a few capacitor swaps. I'll revisit this I think. Anyway, the geometry of the coil (7 mm diameter and length) gives about 120 nH using the Wheeler formula, and my inductance meter agrees. Some empirical capacitor swapping and trimmer jig twiddling later I arrived at a bandset (C5) of 10 pF and bandspread (C6) of 22 pF, giving a tuning range of 86-110 MHz, give or take. The stray capacitance that fits this is around 4.5 pF if I've done the math right. For comparison, my capacitance meter says the detector drain looks like 21.8 pF, but that is without a drain current, having the inductance disconnected, being measured at AF, etc... I'm happy, it tunes the whole band well.

Notes

Component substitution: The J310 is obsolete, I just happen to have a lot of them. Any RF FET should be a suitable replacement. The MPF102 is quite suitable. The MPSA18 could be replaced by any NPN signal transistor if you don't mind burning a bit more current. I'd recommend a low-noise device with good gain like the BC549C or BC550C. You'll obviously need to experiment (calculate) new resistor values for the audio stage if you change the transistor, the circuit is not particularly B independent.

You might like to play with the quench frequency by altering R1 and C1. The selectivity is at a minimum 4 times the quench frequency. Lower quench frequencies become audible and will mix down higher signal components. If you want to place the quench below 15 kHz you'll need to add much better filtering, perhaps a Sallen Key filter or two. Higher quench frequencies reduce the gain somewhat, so pushing it too high is a bad idea. The FM stereo MPX signal has energy to around 56 kHz, more if there are SCA services. Typically the quench is set around 30 kHz (8 kHz into the lower L-R sideband), but as discussed it will vary with signal strength and the modulation. The quench will tend to mix down the L-R sidebands and/or beat with the pilot tone at 19kHz. The result can be absolutely horrible to listen to, especially when the quench is getting pulled around by the modulation or the L-R sidebands are especially intense (lots of stereo difference content). For purely mono signals the recovered audio can be reasonably high fidelity if you position the slope properly. For AM signals (i.e. The Airband) the receiver is especially affective.

L2 is not especially critical, it is just an RFC to isolate the RF signal at the source from being shunted by the quench oscillation capacitor. Anything that gives > j1 kΩ of reactance should be fine, so 1.6 uH or more is sufficient, perhaps a little less would still work. The 10 pF feedback capacitor is about -j160 Ω at 100 MHz, anything at least 5-10 times larger in magnitude than that should be fine. The RFC specified has about j15 kΩ of reactance. A few turns on a ferrite bead will work, as will an RFC wound on a high-value resistor. Just make sure the inductor's self-resonant frequency is far above the frequency of interest so it is still inductive. It is difficult to make an inductor too large at VHF that would upset the circuit that isn't already looking very capacitive.

L1 and the associated C5,C6,C7 capacitors can be changed to put the receiver anywhere you like from high-HF to low-UHF. My particular receiver topped-out at 235 MHz with the 120 nH coil (indicating a stray capacitance of around 4 pF which is in reasonable agreement with the bandspread capacitor calculations), but could go much higher with smaller inductances.

Putting the radio on 10 metres is an interesting idea, it isn't especially difficult to build a miniature AM transceiver using this as the receiver, if you had enough poles on your TR switch/relay you could use the same transistor for the TX and RX, even the same tank. Similar ideas were explored years ago when frequency stability standards weren't what they are now. I've seen articles describing construction of 2 metre HTs using pairs of nuvistors or acorn tubes with free-running LC oscillators on TX and RX, switching around the cathode circuit to achieve either super-regeneration for RX or plate-modulated smooth oscillation for TX.

29 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	16.509 kbytes

Alan's Lab

me and my geeky hobbies

search

Home Twitter YouTube Calculators

MK484 MW Receiver

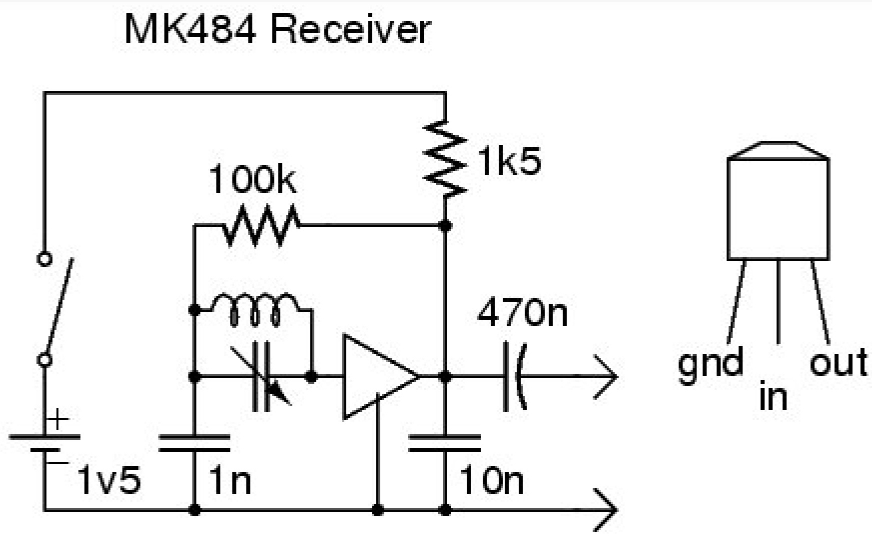
2007-03-24

I've grown tired of my

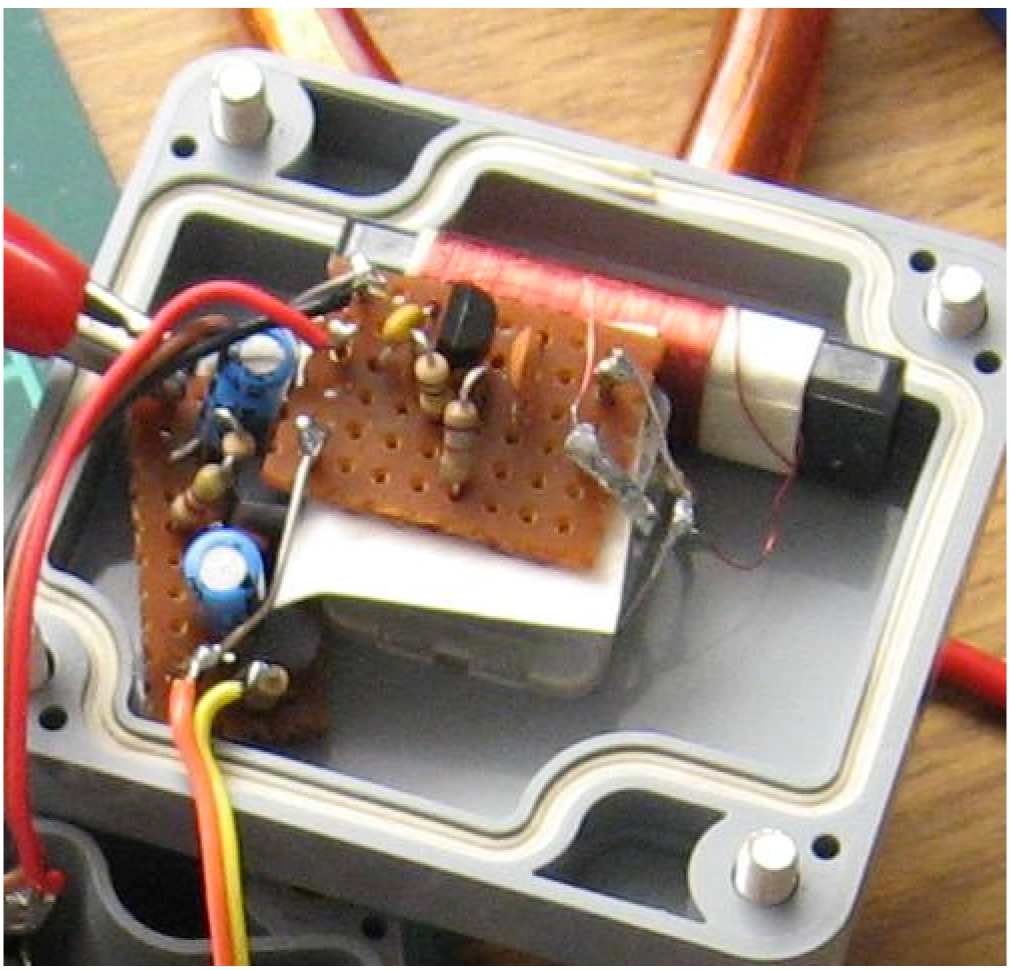
regenerative AM broadcast receiver's lack of AGC and its RFI problems, so I decided to build something based on the MK484. I've had them laying around for years in the junk box, and my recent work in using them for an AM receiver IF prompted this project.

Other requirements for this project were a small size, something smaller than the current plastic tub I carry in my backpack to work every day, and something with a calibrated tuning dial to take the guess work out of tuning. I also set myself a challenge to build it using only a single 1.5 volt cell for the supply, and driving conventional 32 Ohm dynamic earphones.

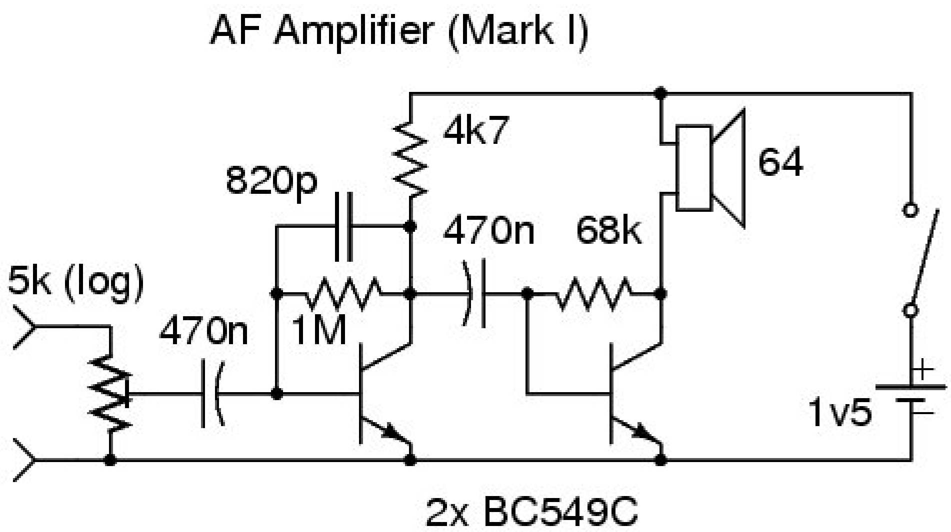
The RF section is very simple, basically the single cell "reference design" MK484 receiver. The ferrite rod is the small rectangular prism unit available from Jaycar or Electus (catalogue number LF1016), I measured its mu-rod at about 65 and calculated the turns required for 400-450 uH or so, required to cover the extended AM broadcast band completely using the 165 + 62 pF tuning gangs also available from Australian electronic stores.



The RF circuit was constructed on a small scrap of veroboard and connections made between it, the rest of the components using PCB pins. At this point the smallest grey ABS box from Jaycar was selected as the enclosure and the polyvaricon tuning gang mounted in the middle of the lid. A knob was selected, large enough for good feel, but small enough to allow a well marked dial to be added later. The adapter hardware from Doug Hendricks KI6DS QRP Kits was again used to mate the polyvaricon with the 1/4" grub screw retained knob. The RF board was "mounted" with stiff wire on the back of the polyvaricon after its trimmers were set for minimum capacitance (a piece of cardboard insulating the track side), and the tuning range customised by removing several turns on the loopstick until it covered from about 538 kHz to 1791 kHz - my overshooting the inductance no doubt a result of the distributed capacitance of the windings. The windings were fixed in place with wax using a candle and the heat gun. The loopstick was then secured to the underside of the enclosure lid with two blobs of 2-part epoxy.

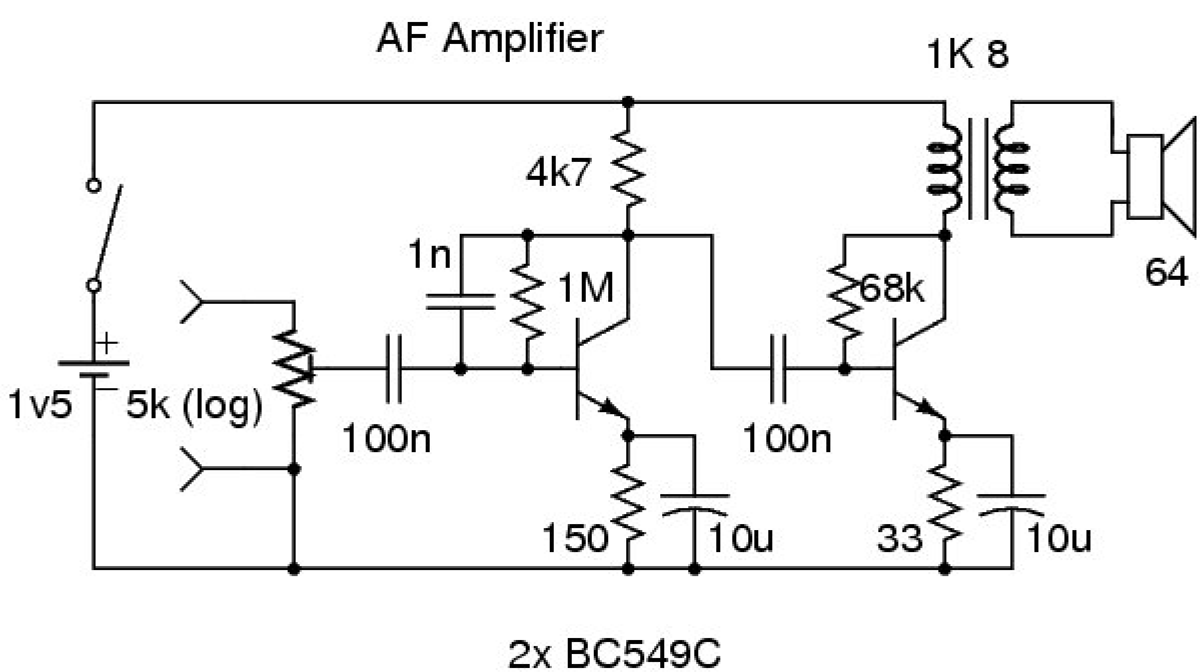


With the RF side of the receiver complete, now came the more challenging bit, an AF amplifier of reasonable performance powered by only a single cell. There have been many "optimised" single-cell headphone amplifiers published over the years, most of them heavily using boot strapping and being quite complex with lots of transistors and large value electrolytic capacitors. I had no where near enough room to fit such a design, so at first I went with a classic two transistor line up that fits on a 4x10 hole piece of veroboard.



In this circuit DC passes through the speakers, and despite some careful design to improve its performance compared to the similar circuit in the Regenerative FM Receiver, I found its performance fairly poor. It offers sufficient gain and undistorted output for a quiet room, but it is completely unsuitable for the kinds of environment I wanted to use the radio in, on my daily commute to work. Its response rolls off at about 15-18 kHz, and the LF corner is quite good due to the largish coupling caps. From 3 volts up, such a circuit is quite usable. If you put a 1K:8 Ohm transformer in the final collector circuit and modified the feedback a little it might actually offer quite acceptable performance.

After using the radio with this Mark I AF amplifier, I decided to modify it for better performance. I picked a transformer coupled circuit to get the best output possible with the low supply voltage. Unfortunately this meant replacing the AA cell with an AAA cell to make sufficient room for the audio transformer.



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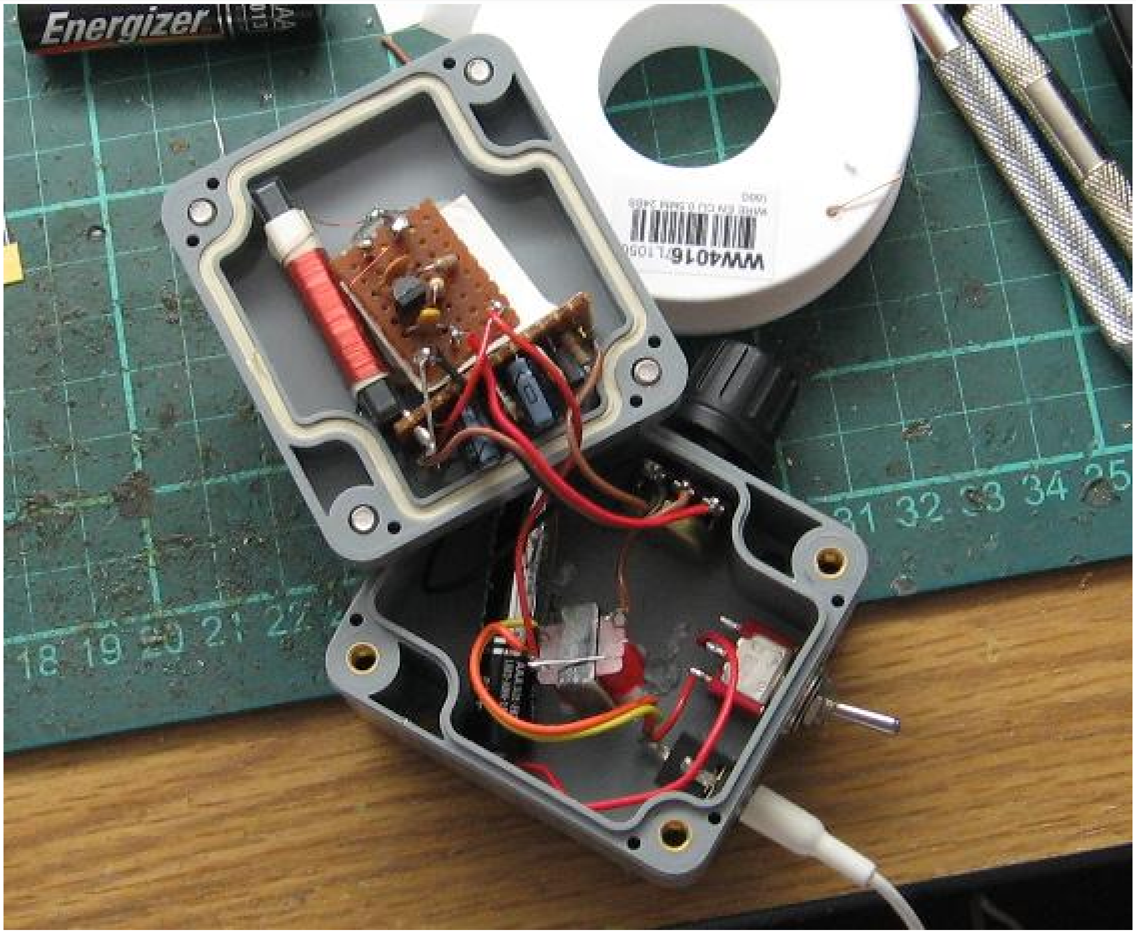
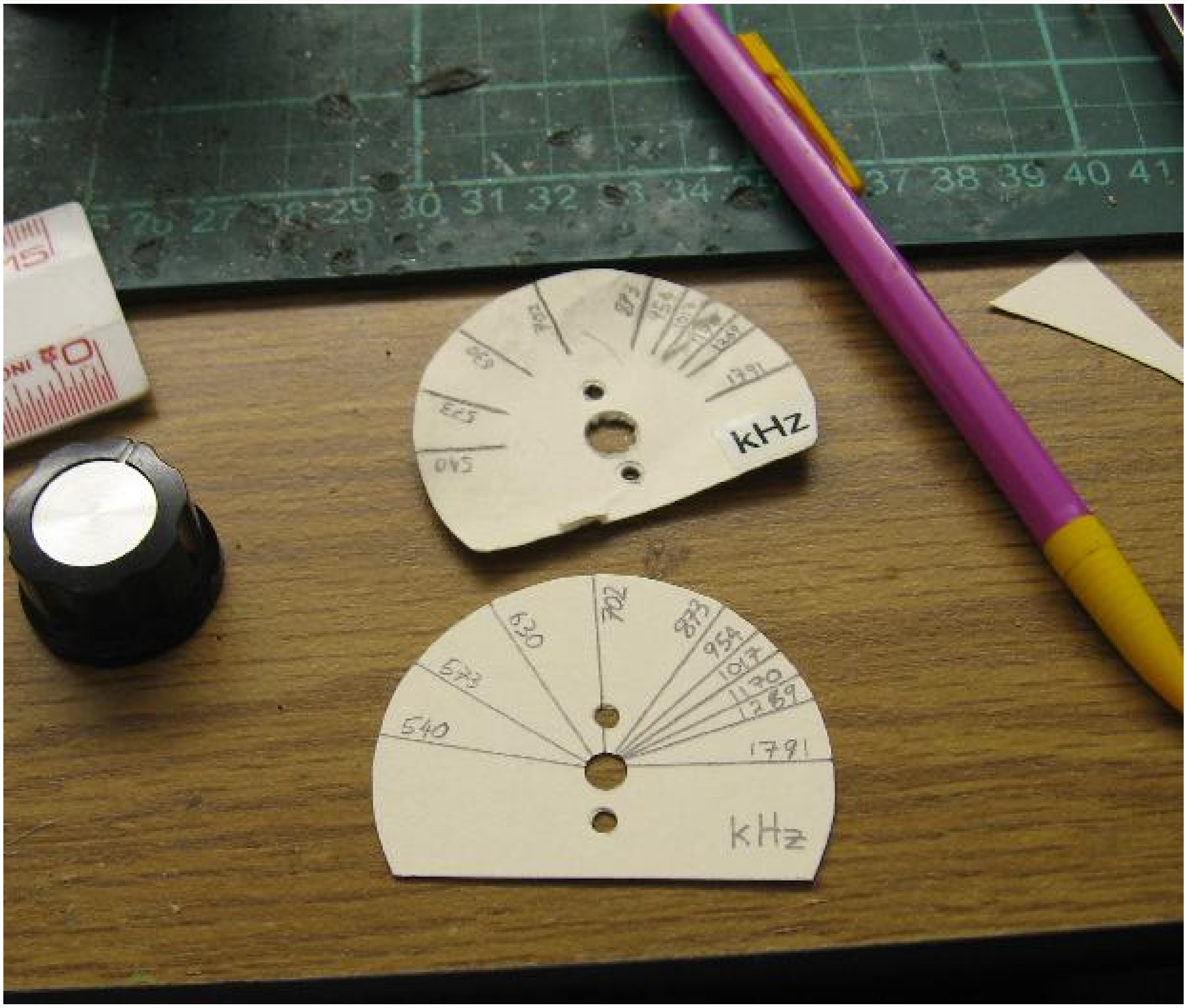


The finishing touches were some labelling using a Dynamo label maker, and the creation of a nicely laminated dial for the tuning knob. I used the XYLs Xyron 510 machine to make a piece of cardboard into a sticky-backed label which was pasted into place. This was marked with the assistance of the signal generator (and off-air signals). This was then peeled off and a final version made using the original as a template. The final version was run though the Xyron machine again using a laminate cartridge to produce a very pleasing glossy result.



Notes

The wall of the plastic enclosure is too thick for the 3.5 mm stereo socket mounting thread. I ended up epoxying it into the wall. With some care I guess you could thread it into a slightly undersized hole, but gluing it right into the hole is much less mechanically challenging, especially if you didn't notice the problem until after you drilled the hole like I did!

As usual, a switched pot would avoid the need for a separate power switch. It would also make the radio more resistant to accidental turning on while it is knocking around in your bag. If only suitable switched pots were a still available from Jaycar or DSE...

The selectivity could be better, 2BL (702 kHz) is an enormous signal at my QTH and can be heard between channels near the centre of the tuning range. It is not all that objectionable, except when trying to chase DX at night - which was never a design requirement. I probably should have used Litz wire for the coil, or tried using one of the commercial pre-wound coils (like Jaycar catalogue number LF1020). Such coils are designed to match the tuning gang I am using, but past experience has suggested their precision leaves a lot to be desired, often being incapable of tuning the entire band even when moved physically on the ferrite bar and using the trimmers on the tuning gang. They are a cheap source of an approximately correct coil that can be tweaked though.

A Q-booster using a simple FET circuit could tighten the selectivity, but it would chew more power and isn't really required for local station work. I am just being picky really, the performance as-is exceeds most bargain-store superhets.

The Xyron 510 machine is a damn handy piece of kit. It can place adhesive on the back of any thin, fairly flat, object, or laminate both sides, or one side and put adhesive on the other. Cartridges are available with a choice of re-positionable or permanent adhesive, it can even make fridge magnets. Its main target market is the scrap booking community, but homebrew electronic hobbyists would find it very useful for panel work.

6 comments.

Attachments

title	type	size
RF Board Circuit Source	application/postscript	13.346 kbytes
AF Board (Mark I) Source	application/postscript	13.053 kbytes
AF Board (Mark II) Source	application/postscript	14.849 kbytes

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2007-03-24

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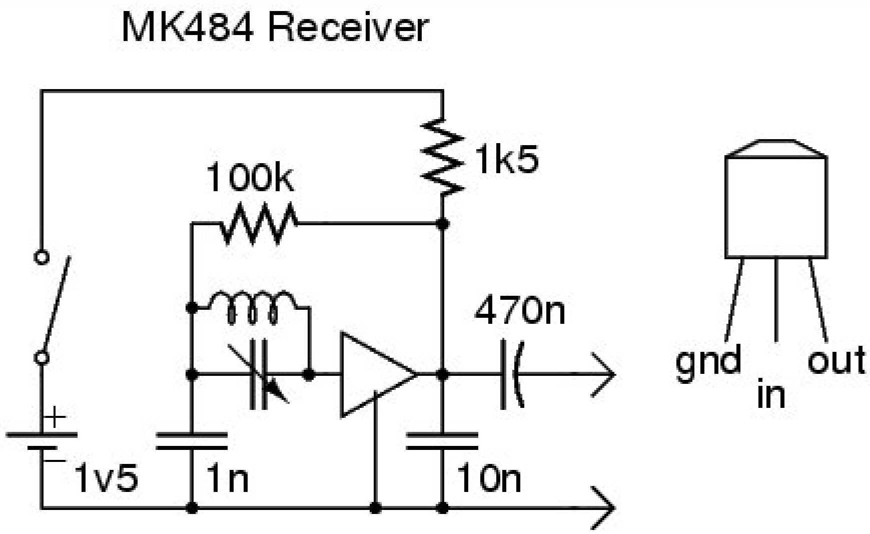

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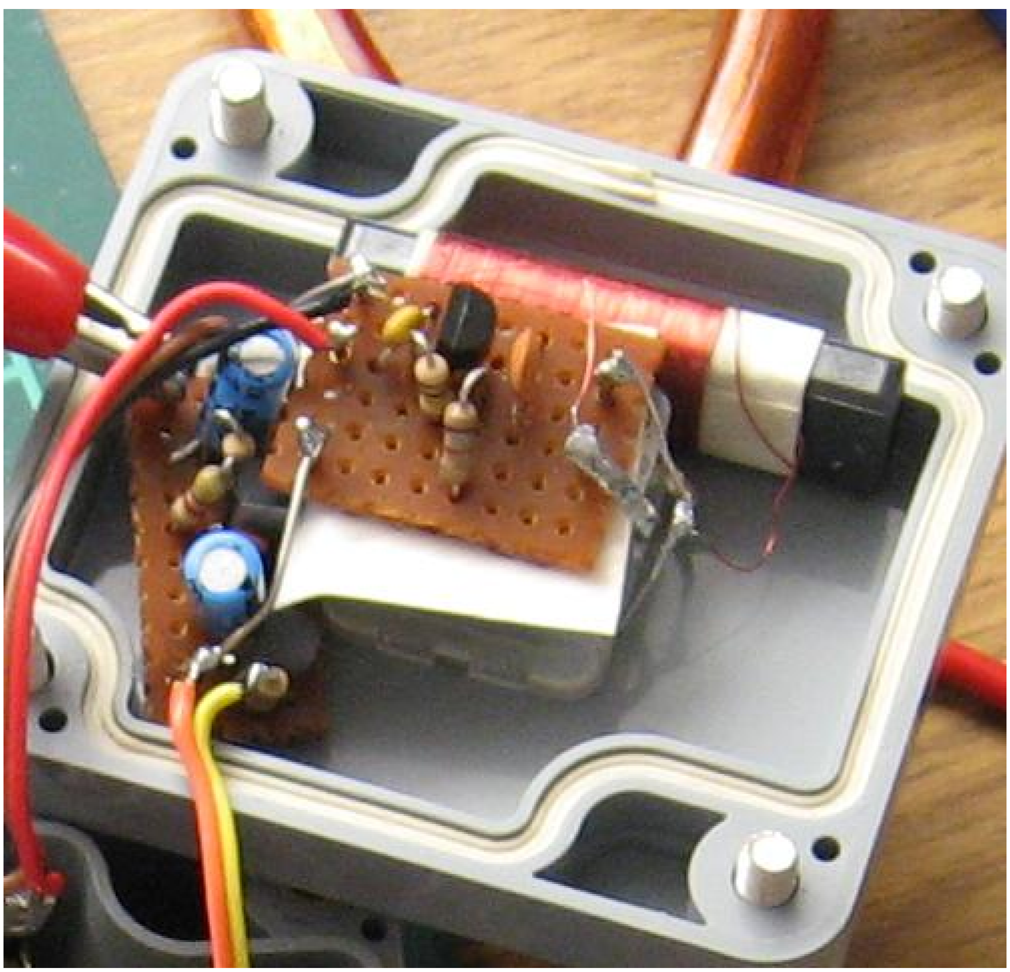

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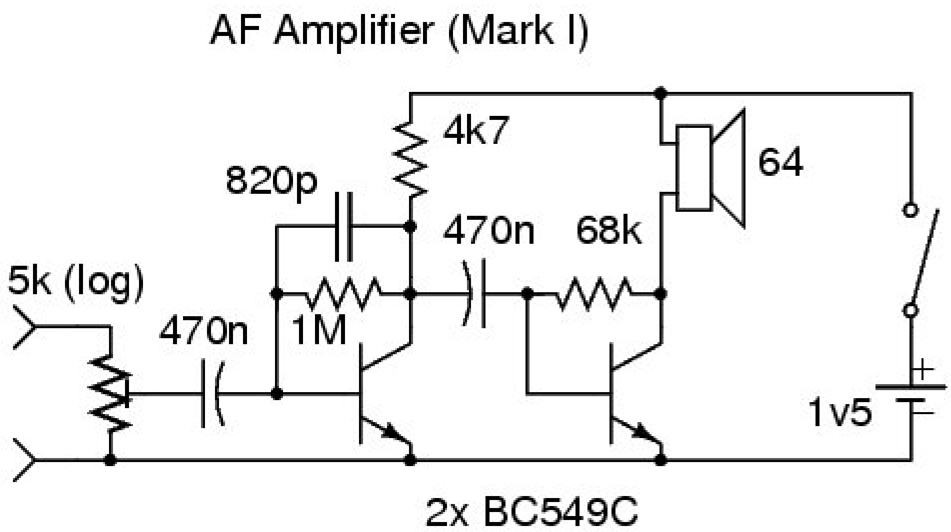

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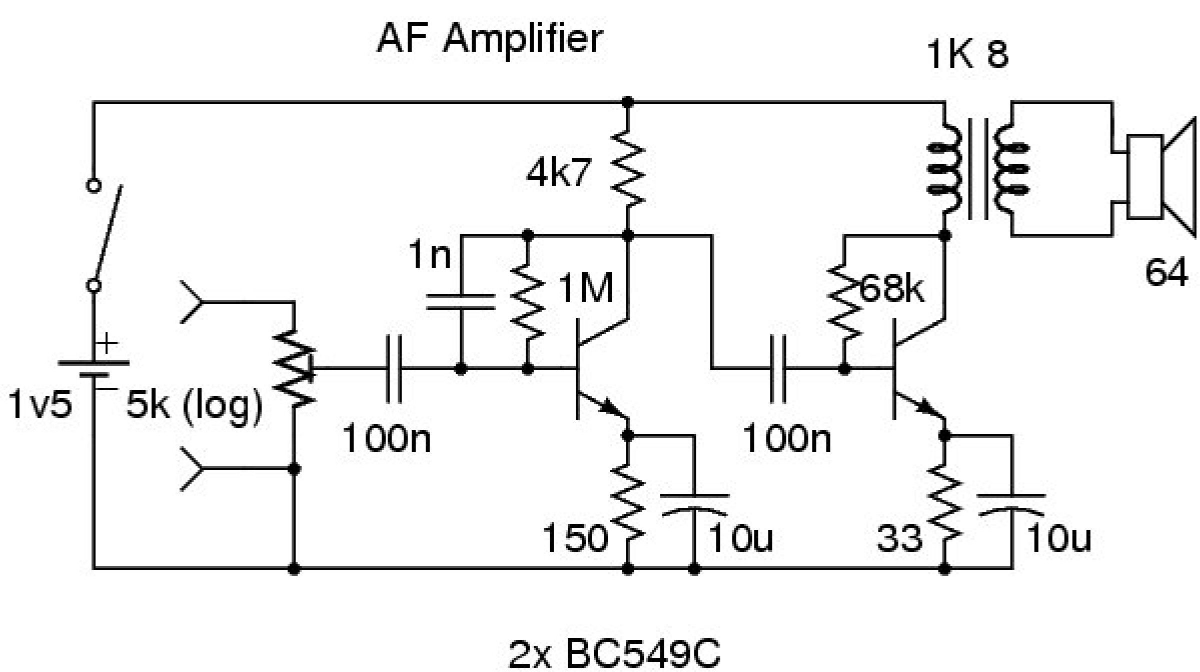

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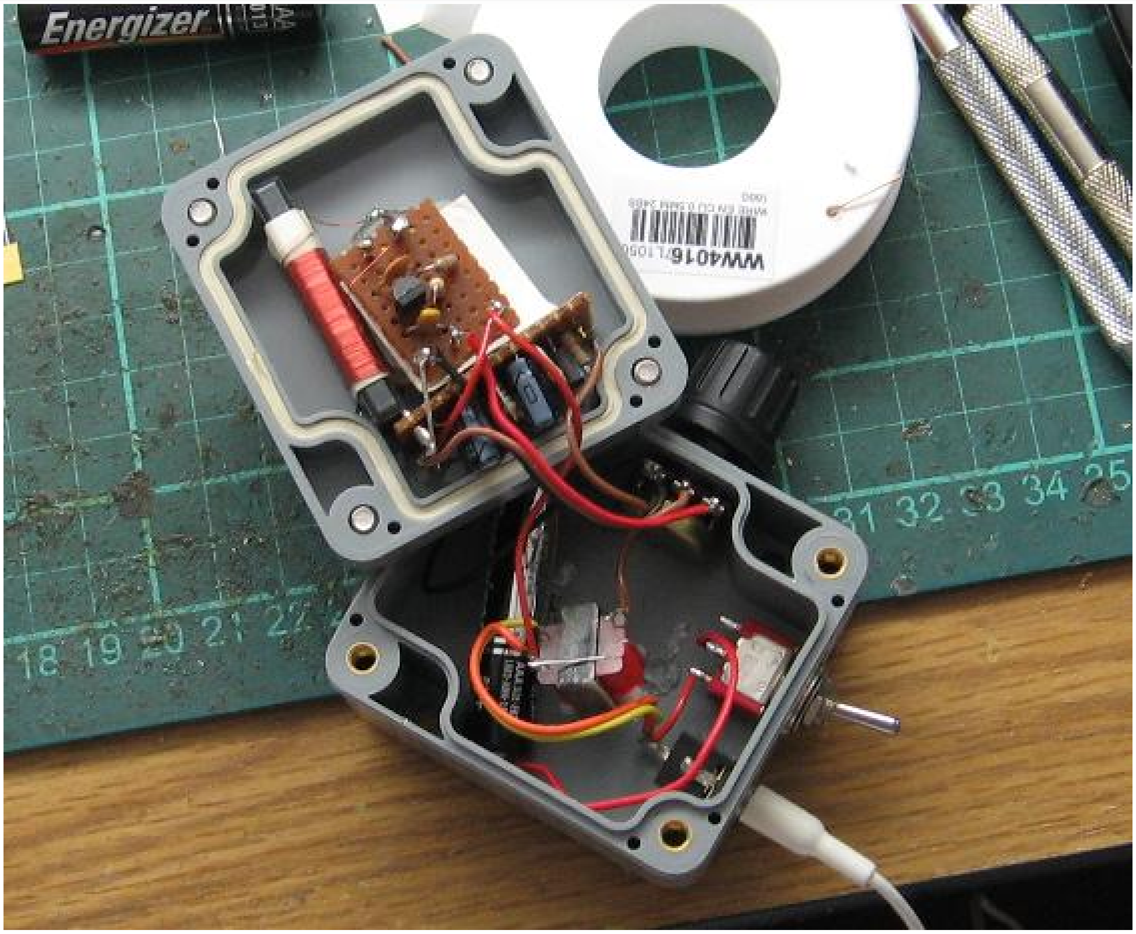

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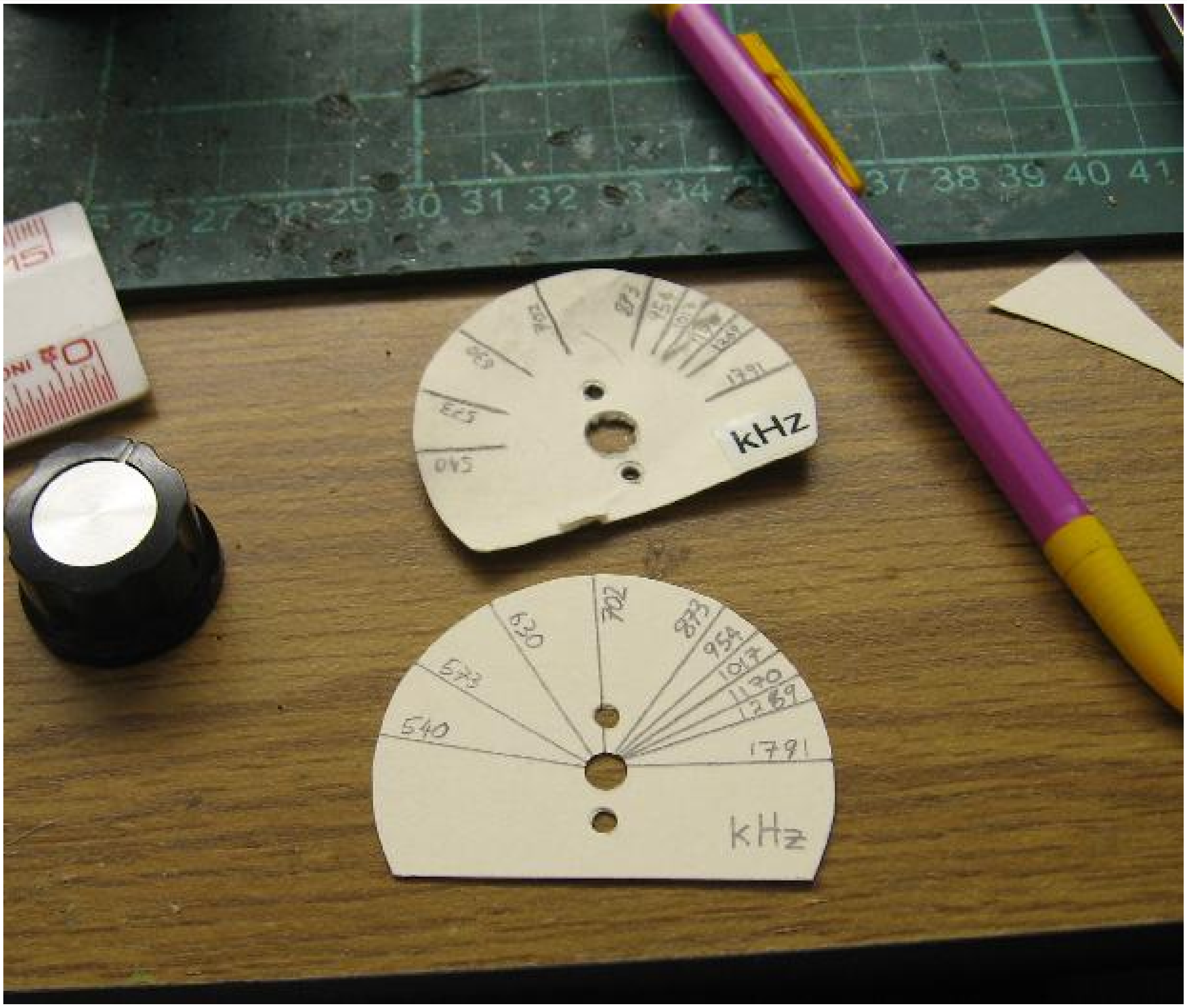


Notes

The wall of the plastic enclosure is too thick for the 3.5 mm stereo socket mounting thread. I ended up epoxying it into the wall. With some care I guess you could thread it into a slightly undersized hole, but gluing it right into the hole is much less mechanically challenging, especially if you didn't notice the problem until after you drilled the hole like I did!

As usual, a switched pot would avoid the need for a separate power switch. It would also make the radio more resistant to accidental turning on while it is knocking around in your bag. If only suitable switched pots were a still available from Jaycar or DSE...

The selectivity could be better, 2BL (702 kHz) is an enormous signal at my QTH and can be heard between channels near the centre of the tuning range. It is not all that objectionable, except when trying to chase DX at night - which was never a design requirement. I probably should have used Litz wire for the coil, or tried using one of the commercial pre-wound coils (like Jaycar catalogue number LF1020). Such coils are designed to match the tuning gang I am using, but past experience has suggested their precision leaves a lot to be desired, often being incapable of tuning the entire band even when moved physically on the ferrite bar and using the trimmers on the tuning gang. They are a cheap source of an approximately correct coil that can be tweaked though.

A Q-booster using a simple FET circuit could tighten the selectivity, but it would chew more power and isn't really required for local station work. I am just being picky really, the performance as-is exceeds most bargain-store superhets.

The Xyron 510 machine is a damn handy piece of kit. It can place adhesive on the back of any thin, fairly flat, object, or laminate both sides, or one side and put adhesive on the other. Cartridges are available with a choice of re-positionable or permanent adhesive, it can even make fridge magnets. Its main target market is the scrap booking community, but homebrew electronic hobbyists would find it very useful for panel work.

6 comments.

Attachments

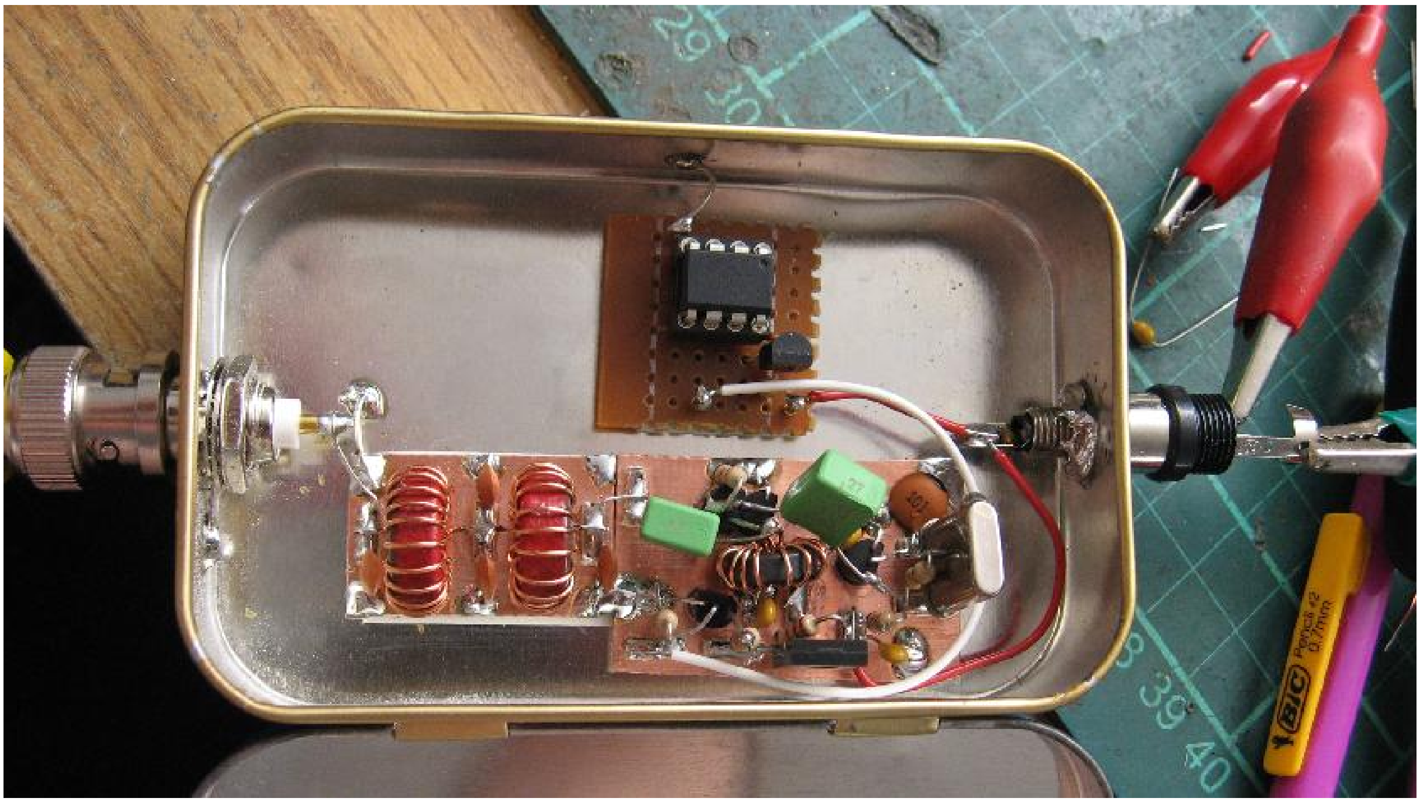
title	type	size
RF Board Circuit Source	application/postscript	13.346 kbytes
AF Board (Mark I) Source	application/postscript	13.053 kbytes
AF Board (Mark II) Source	application/postscript	14.849 kbytes

More Beacon Work

2008-06-29

Beacon Transmitter

I put the 80 metre CW beacon into an Altoids tin. This worked quite well shielding the unit far better than expected despite no effort having been made to decouple the DC input feed. With a dummy load the signal is hardly detectable across the room. The boards are held in place with double-sided foam tape, short wires connect to the tin for grounding where required, power comes in via an RCA socket.

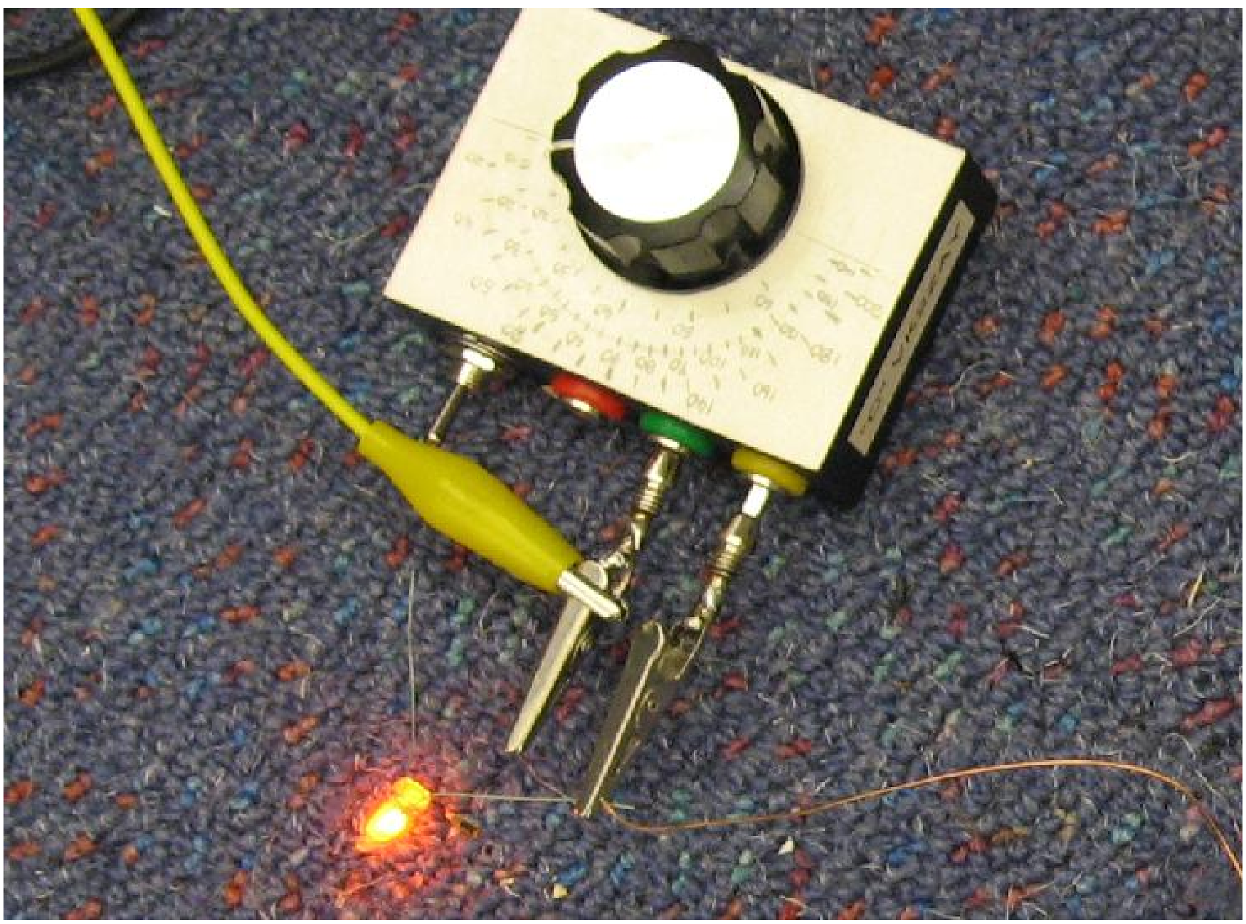


Antenna Work

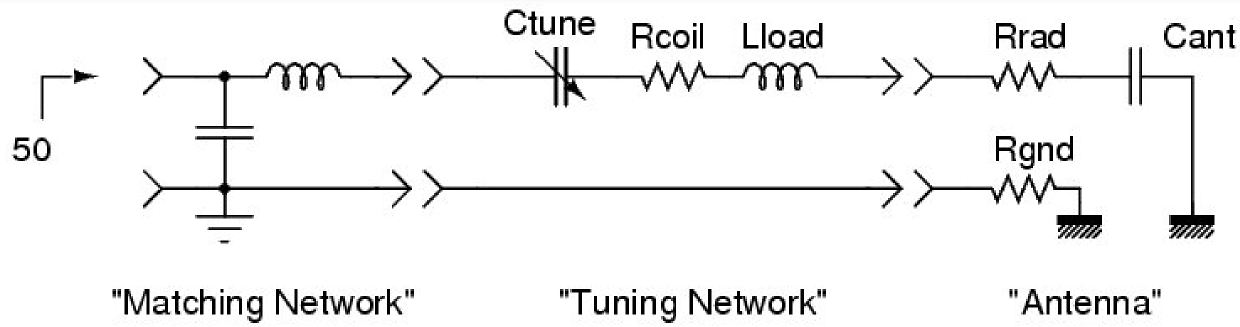
Previous quick experiments with a ferrite base-loading inductor were reconsidered when I felt how hot the inductor was getting. Almost all the transmitter power was being dissipated in the core! Calculations and common sense about high-Q inductors suggested I needed copper wire gauges and coil former volumes I just didn't have in stock, so an order was placed for materials. In the meantime I wound a 159 uH inductor using 0.5 mm wire close-wound on a piece of 25 mm OD conduit. Neatly hand-winding 150 turns without a winding jig is a process that requires much patience, my hands where cramping at the end of the job. The self-resonance frequency of the inductor is about 10 MHz (confirmed with my super-regen dipper), the aspect ratio was chosen to minimise self-capacity of the coil while still having a reasonable Q, while "squarer" coils often have better Q for the same wire gauge they have more self-capacity and hence a lower SRF and peak-Q frequency. This inductor has a Q-peak estimated near 2 MHz, so it is being operated non-optimally. Not being space-wound and in full contact with the former is the largest Q-limiting factor.

While not ideal, this inductor dramatically improved the antenna performance, allowing Peter VK2TPM to hear my feeble signal at his QTH and even read parts of it. Here is a short recording he made after the inductor change. Prior to this he could just tell there was a signal there, but not read it.

The new inductor is somewhat larger in value than needed, my C-jig is used to reduce the effective antenna capacitance and tune to resonance with the fixed inductor. Resonance is quite sharp (a good sign - means the Q is fairly reasonable), and the RF voltage delivered into the high antenna impedance (kilo-ohms in magnitude) is quite high, enough to ionise Neon NE-2 bulbs held near the coil.



This voltage is not healthy for the C-jig polyvaricon BTW, it resulted in a flash-over of the small trimmers on the back of the polyvaricon causing a small region of carbonisation in the insulator edge. This gave an intermittent fault that only appeared as resonance was approached and the voltages rose high enough to flash to the burnt spot - the trimmer insulation was carefully scraped cleaned and the trimmer position displaced slightly from minimum reducing the 'sharp edge' field concentration curing the problem, but the final matching network will use an air-spaced trimmer of higher voltage rating. At higher powers I have no doubt you could destroy a polyvaricon quite easily.



Essentially the antenna appears as a small capacitance (Cant - 10-30 pF) in series with a resistance which is composed on a small value which models actual signal radiation (Rrad) and a larger value that models the losses in the ground system (Rgnd). The coil has its losses modelled as a resistance as well (Rcoil), but basically the entire system resistance appears lumped together once Cant is tuned out by Lload (and Ctune, which acts to reduce Lload and/or Cant). This total antenna resistance must then be matched back to our transmitter output load resistance, 50 Ohms in this case. The inductive part of the L-matching network could be absorbed into Lload but I decided not to do this enabling each section to be tested separately.

Matching is important because the filters and output devices in the transmitter were designed to operate with a 50 Ohm resistive load, reflecting smaller resistances (or more pathological reactive impedances) back into the transmitter can make it pull too much current destroying its output devices or cause it to generate spurious signals. Larger resistances are fairly safe with this particular design, it just tends to poorly load the unit and result in very little output power. Especially bad is inductive reactance which can result in resonances in the output stage and frequency multiplication preferentially producing higher harmonics resulting in overheating - this is unfortunately easy to achieve with the L-match feeding scheme and happens close to the optimal resistive match because of the sharpness of the tuning.

Two different feeding schemes have been trialled; initially my trusty end-fed half-wave antenna matching unit was used instead of an L-network, having just sufficient range to match the moderate resistance (hundreds of ohms) of the resonated antenna. More recent work involved careful measurement of the antenna resistance at resonance (near 300 Ohms) and design of an L-network to match this to 50 Ohms (5 uH inductor and 330 pF capacitor in a low-pass configuration). A pair of 10 uH Ohmite chokes in parallel were used and a silver teflon capacitor from the junkbox, network Q is around 2.2 so the values and component performances aren't especially critical. At resonance the Γ seen looking into the matching network is < 0.15 which is a VSWR better than 1.35:1.

The 300 Ohm resonant load resistance figure suggests very high ground losses (Rgnd), I am using the cast iron sewer back-vent of my building as a ground system, it may not be well bonded at each joint. The radiation resistance is estimated to be in the 1-5 Ohm region for this length of wire, so the total system efficiency is 1.7% at best and perhaps as little as 1/3 of a percent! Radiated power is therefore in the 450 uW - 2.5 mW region ignoring mismatch and any other losses I can't quantify.

Enough to say it isn't getting out very well at present, better antennas are in the works though.

14 comments.

Attachments

title	type	size
Antenna Network Circuit Source	application/postscript	12.276 kbytes

Parent article: 80 Metre CW Beacon.

More Sports Ears Related Musings

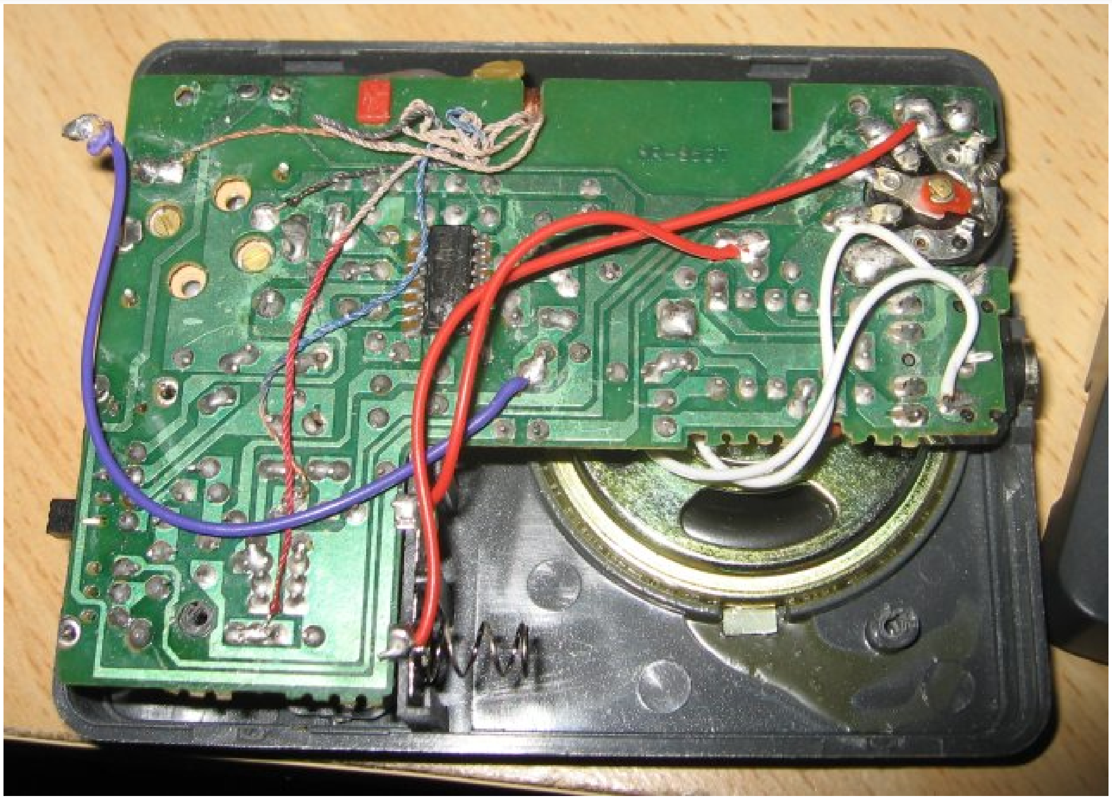
2010-05-12

A Cheaper Compatible Receiver

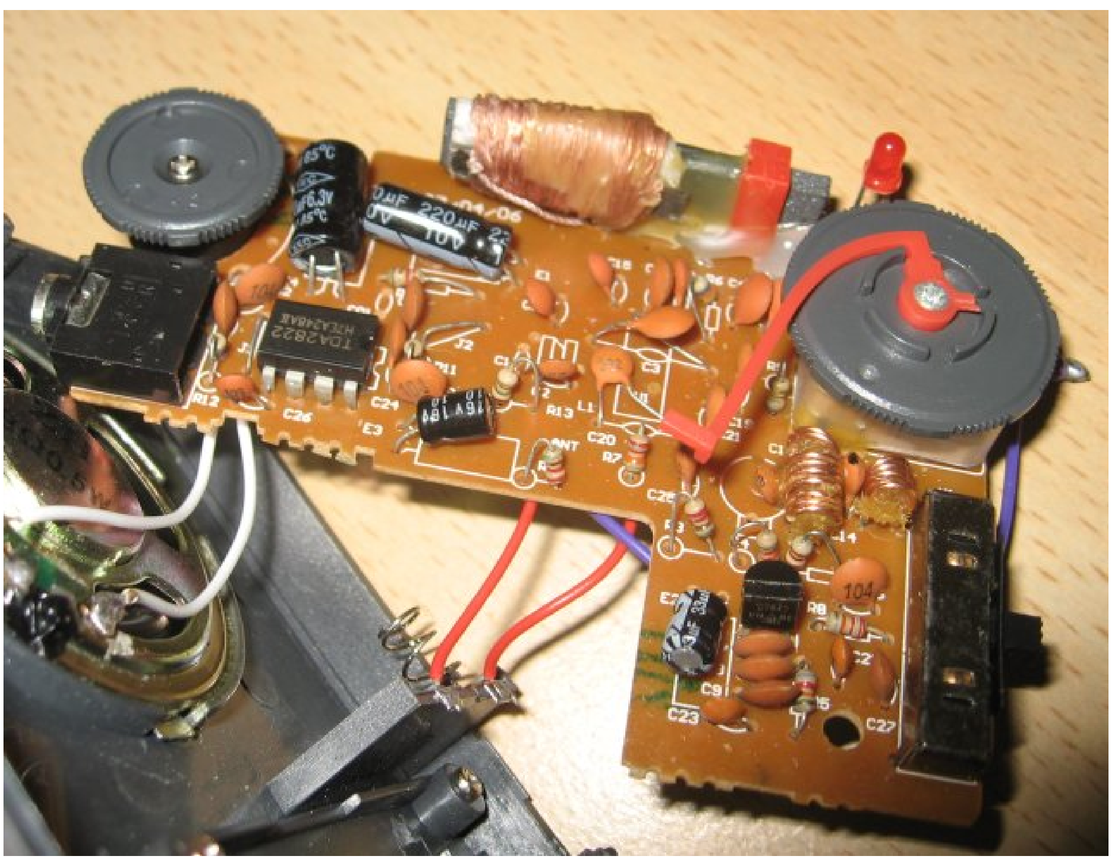
Checking eBay the other day I found a 3-band consumer radio that covers the Sports Ears frequency for $5.48 AUD. Naturally enough I ordered it to check out. The shipping was about $5 on top, so < $11 landed. Apparently you can also order it direct from the Suntek store and get free shipping. The unit is "Kaide" brand, model designator "BC-R30". It is a little physically larger than the AFL Sports Ears product, with 2 VHF FM bands and MW. Turn-the-dial tuning, covering 64-86 MHz, 86-108 MHz and 530-1600 kHz.

It operates from two AAA batteries, pulls about 17 mA quiescent on all bands and features a red LED power indicator. It has a small telescopic antenna, a front-panel speaker and a 3.5 mm stereo headphone jack. The FM detector is only monophonic, but like the Sports Ears unit (and unlike so many cheap radios) the actual socket is wired to support stereo headphones not the mono magnetic ear piece of years gone by. Unlike the AFL Sports Ears unit its dial indicator is easy to read, and even at full (ear-splitting) volume the audio amplifier has very little distortion. The unit does not come with earphones, one must provide their own if they desire private listening.

The front panel speaker offers flexibility that none of the Sports Ears range have - perhaps by design. One could say so as not to annoy near-by fans in the stadium, or perhaps because of its limited practicality in the noisy stadium environment. Less charitably, to minimise costs and encourage more sales.



Inside, the BC-R30 is based on the CD9088CB (a TDA7088 clone). This particular chip is vaguely similar to the old TDA7000 low-IF (70 kHz) with FLL detector architecture and is aimed at the very cheapest end of the FM broadcast receiver market. It provides acceptable quality FM detection and features scan/reset varactor or turn-the-dial polyvaricon tuning with or without AFC. Being low-IF with FLL recovery it has rather weaker selectivity than the ceramic filtered quadrature detector system used in the genuine Sports Ears unit. As supplied I found the mute circuit annoying, so I changed R6 to 10 kΩ to disable the mute. I also personally find the capturing effect of the FLL demodulator annoying, and prefer the smoother tuning of other architecture FM discriminators. That said, the unit is sensitive and more than adequate for the task, even with the mute unmodified.



The MW feature of the receiver is based on the CC7642 AM TRF 3-pin TO-92 chip (a clone of the TA7641 which is a clone of the old ZN414 or MK484). The arrangement is even simpler than that suggested in the TDA7088 datasheet for an AM/FM solution

which utilises the CC7642 at a 455 kHz IF using the TDA7088 as an RF amplifier and mixer. Rather the CC7642 works directly at the RF frequency as a TRF receiver. The drawback is absolutely pathetic selectivity, especially with the fairly poor Q of the loop-stick used. One can hear 2BL 702 kHz across most of the band for example, even under some of the weaker stations towards the top of the band.

Indeed, this receiver is built for a price and it shows it. There is little else you could remove and still have a functional receiver. The genuine Sports Ears unit has a technically much more advanced architecture, especially on MW where it is a single-conversion superhet and uses a ceramic filter for much better performance. The BC-R30 has no IFT cans or ceramic filters in it at all, in fact only three inductors, the two VHF LO tanks for the two FM bands and the MW loop-stick antenna, there is no front-end track-tuning tank on VHF! This is a "feature" of such minimal AM/FM receivers which minimises the production costs and simplifies the factory alignment requirements.

The lack of a track-tuned front-end means the FM detector will also harmonically detect out-of-band transmissions. For example, on the "SCH" band, I can easily hear TV channel 7 audio (187.75 MHz) near the bottom of the dial "64". this is a 3rd harmonic response: LO = (187.75 - 0.07) / 3 = 62.56 MHz. (I confirmed this by listening to the LO using my VR-500, the LO being locked to the RF signal by the FLL is WBFM modulated by the signal being received.) This harmonic mixing is either a feature or a major limitation depending on what you want to listen to. For the 70.2 MHz Sports Ears channel the harmonic spur and image responses are in sparely populated regions of the spectrum and will likely cause no problems.

Still, none of these limitations of the BC-R30 make the Sports Ears receiver look like a great deal. The Sports Ears receiver costs 8 times more than BC-R30. At least with Sports Ears you are getting a real superhet with fairly good selectivity. It is arguable that fixed "UMPS" tuning is also preferable as you do not need to retune, and can flick between your favourite FM station and UMPS easily. The Sport Ears receiver also pulls a little less current, so its batteries will last somewhat longer. That said, the BC-R30 is quite usable if you don't want to buy the genuine product.

The big feature of the BC-R30 is the TDA2822 audio amplifier. Even at only a 3 volt supply it can deliver several hundred milliwatts of audio at very low distortion. That combined with the front-panel speaker and better treble response makes the BC-R30 a pretty nice radio for casual use, especially as it covers part of the VHF TV band, and for the price is fairly competitive to the Digitor/Tecsun receiver available from Dick Smith I suggested as another alternative.

Converting a Common AM/FM Radio

For comparison purposes, I picked up a $12 AUD "Sansai" AM/FM radio at Hot Dollar in Cronulla. It is a fairly bulky unit, has a monophonic earphone socket, and a really pathetic dial scale pointer that sometimes sticks. It tunes the usual 88-108 MHz and 530-1600 kHz bands. It has a belt-clip in addition to the lanyard shared by the other receivers and runs from two AA batteries making it a bit cheaper to feed although it pulls about 20 mA quiescent despite having no power indicator LED. There are no screws holding the shell together, just rather fragile moulded clips.

Inside that extra $5 shows, the radio is arguably better engineered than the BC-R30. It is based on the SA2003 (a TA8164 clone). This chip implements a full superhet AM/FM receiver with AM AGC and a quadrature detector for FM. The implementation utilises track-tuned circuits for both bands and ceramic filters/quad network. It just happens to use the TDA2822 audio amplifier. Why it only has a mono earphone socket despite a dual-channel amplifier is a bit of a puzzle.

The MW selectivity is provided by the 455 kHz ceramic filter and is fairly similar to the Sports Ears receiver. Needless to say, a vast improvement over the BC-R30's MW receiver.

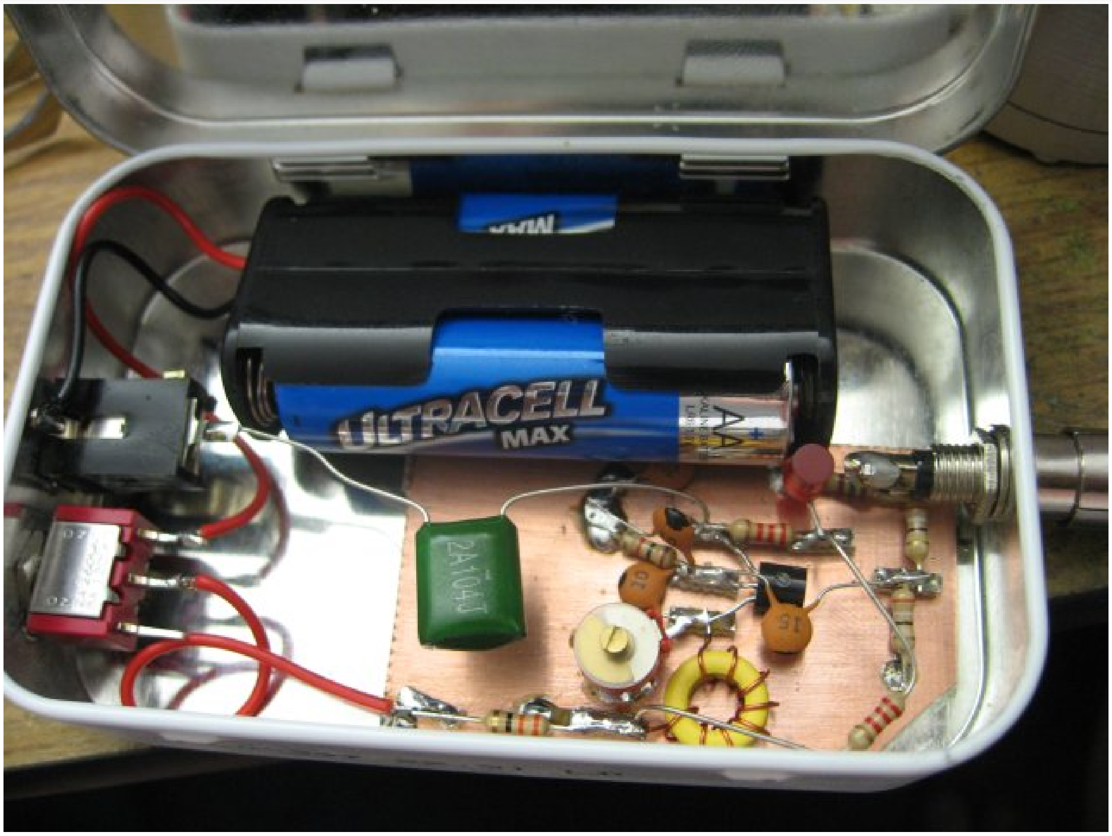
For VHF WBFM the ceramic quadrature network based detector is actually a little touchy to tune compared to the LC quadrature network detector in the Sports Ears receiver. I am unsure if the ceramic IF filter pass-band does not exactly correspond to the ceramic quad network or if the filter itself is a little too narrow, but distortion on deviation peaks is noticeable unless tuned exactly on frequency with a strong signal. Despite the locking effect of the FLL in the BC-R30 I think I prefer its detector for overall quality of recovered modulation with less than precise tuning.

Anyway, conversion was a simple affair. Although I had hoped there would be enough adjustment range in the existing coils, this was not the case, I was forced to replace the oscillator and front-end tanks. I replaced the LO coil with a 5 turn one (5 turns on 5 mm ID, 700 um tin-plated Cu wire) and replaced the pair of bandset caps (an 20 pF and 30 pF) with a single 56 pF capacitor. For the front-end tuned circuit I replaced the coil with a similar 5-turn coil and needed about 10 pF extra capacitance across the existing gang + bandset cap to place 70.2 MHz mid-dial. The turn spacing was tweaked with the tracking trimmers at mid-swing. The resulting receiver works just fine, but doesn't quite track-tune properly. This is of no consequence for use with just Sports Ears, and I did not believe it was worth the effort to unsolder and measure the polyvaricon properties to compute a L & C solution for near-perfect tracking.

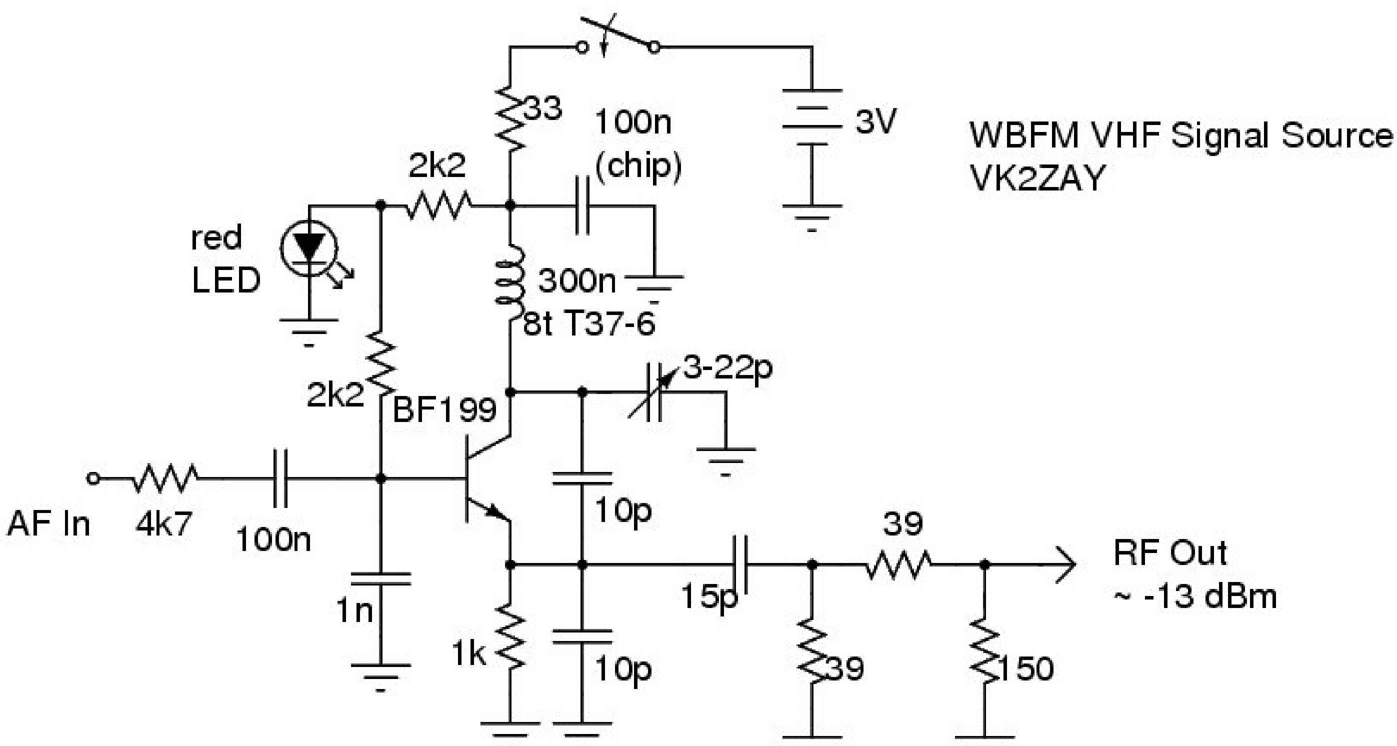
When I said "trivial" affair in my previous article, I may be exagerating a little. Without test equipment, especially a signal generator and frequency counter this task would have been pretty daunting, especially if you want to preserve proper track-tuning or add band-switching. I found my wavemeter and tone dipper especially helpful for this realignment, more so when I got completely lost and couldn't sniff enough LO energy to drive the counter properly.

A Signal Generator For Testing

In order to locally test receivers and converters for the Sports Ears frequency I built a simple test source. It is carefully shielded with a fairly weak output power and internal PSU so the signal can be attenuated to very feeble levels for sensitivity testing. When terminated in a dummy load the signal is undetectable near unit. Despite no special precautions being taken with the AF connector line to prevent RF leakage, very little escapes there. Originally an internal AF oscillator was planned, but was found to be unnecessary and the socket added to allow a range of audio sources to be used for testing.

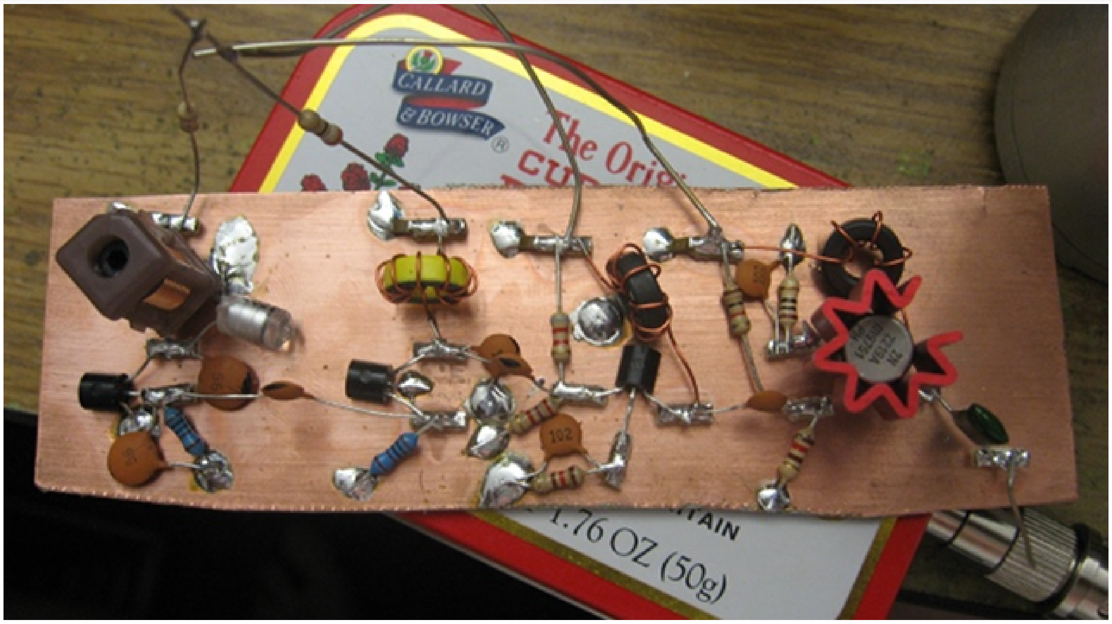


The circuit delivers about -13 dBm into 50 Ohms and has sufficient stability for the purpose. It tunes about 52-90 MHz with the values indicated. The LED based transistor base bias is to allow operation from a wide range of supply voltages (near constant emitter current). This was more useful during testing than in the final circuit with its 3 volt battery supply, you may fix the base bias with resistors if you prefer.



The oscillator is very conventional, grounded base Colpitts topology. I used a T37-6 core for the tank coil and it seems to offer sufficient stability, even without embedding it in wax. A trimmer allows tuning to the frequency of interest (in this case 70.2 MHz), and it will only drift 50 kHz or so over an hour once set and drifts much less once completely warmed up. The base bias is modulated by the audio signal to provide quite reasonable frequency modulation, with only a small amount of parasitic AM. Deviation achievable far exceeds that required for FM broadcast band standards (75 kHz).

Incidentally I also built a quick hack that delivers several hundred milliwatts which I'll only provide a photo of. Not so much because I

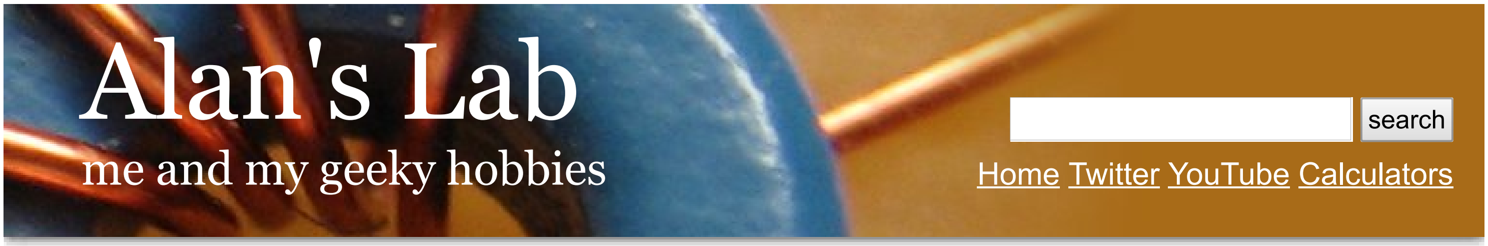


As you can see, it has no output low-pass filter and matching. It is rather inefficient, pulling about 1 Watt DC. The multiplier stage is very coarsely tuned and the output is not very pure, but it works for higher power testing with external clean-up gear.

9 comments.

Attachments

title	type	size
VHF WBFM Signal Generator Circuit Diagram Source	application/postscript	15.001 kbytes



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Multimeter RF Power Add-On

2007-09-09

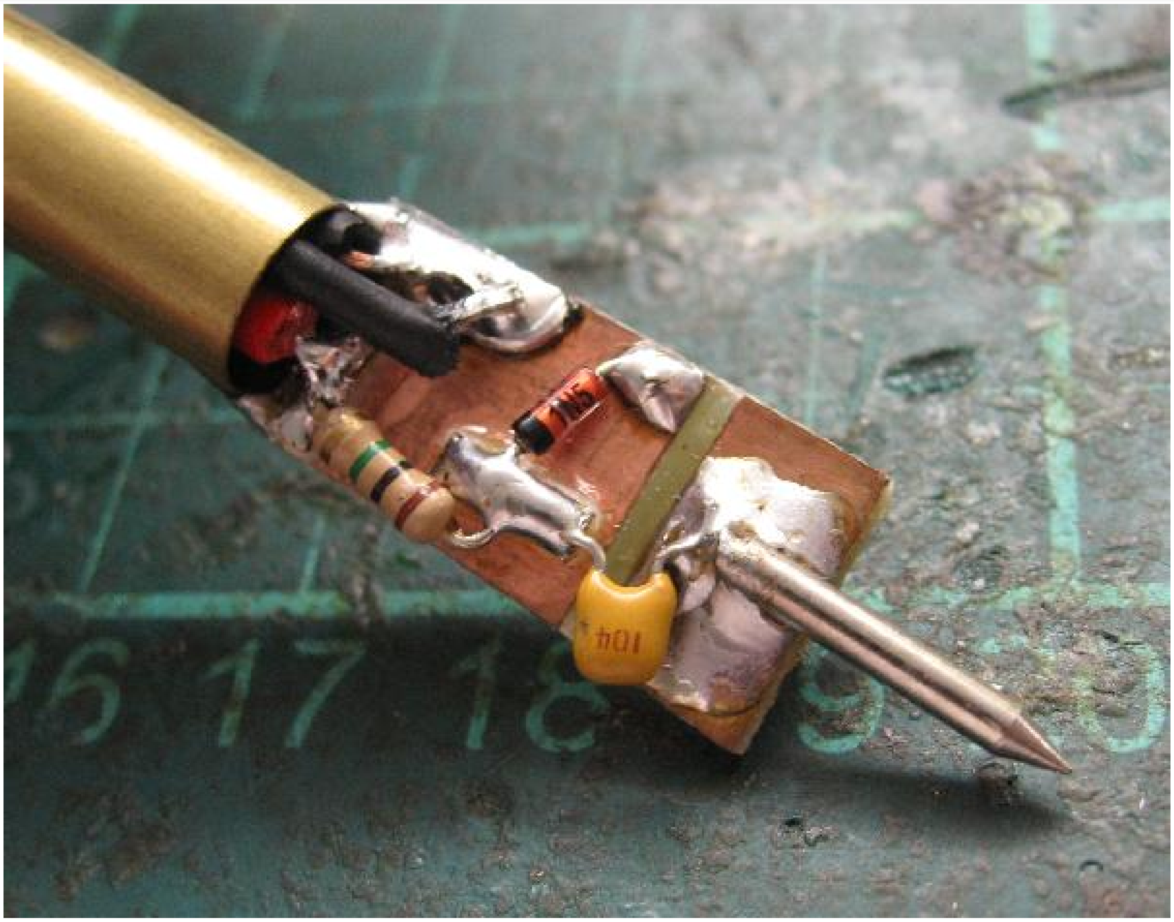
Being able to quickly measure RF power from -10 dBm to + 30dBm is extremely useful. This simple 50 Ohm load with inbuilt diode peak voltage detector fits the bill. Unfortunately it must be calibrated carefully and isn't direct-reading, but a simple table of Voltage or Current measured to delivered dBm can be constructed and kept near the unit.

I wrote a short program to generate a table of the Voltages, RMS, Peak and Peak-to-Peak that represent -20 dBm to +30 dBm. The formulae might be simple, but the table is useful for ball-parking, and was used to calibrate the meter at DC.

Calibration at DC isn't perfect, RF will read slightly differently as the dynamic properties of the diode vary. However it is extremely easy to just dial up DC voltages on your bench PSU and write down the corresponding reading on the multimeter.

If you use 75 Ohms more than you use 50 you might build and calibrate yours for that impedance. The load resistors will tend to dominate the frequency response, but the detector itself does affect the high-frequency return loss. The resistors and layout I used are only really suitable to low VHF, but for my immediate uses that is sufficient.

Build yourself a diode probe too (there is a 470p chip capacitor hidden under the wires).



Unlike the power meter the diode probe is designed to only load the circuit very lightly, measuring the peak RF voltage at the point under test. As the impedance of the particular point in question will vary it can only use used for relative measurements so there is little point calibrating it.

Notes

The diode is a 1N5711.

The 10 nF capacitor directly across the meter plugs is to prevent RF from upsetting the meter (smaller values using ceramic or chip caps might be more appropriate at higher frequencies). The budget meter show is actually very resistant to RF interference compared to some of my other multimeters, my old DSE Q-1418 did not like the RF at all once more than a few dBm was delivered. (Meter show is a Jaycar QM-1500, about $8 AUD. For the price you may as well just dedicate one to this service.)

The 1 KΩ resistor in series is to limit short-circuit currents to something that won't zap the diode. It is small enough to be effectively ignored when looking at the peak voltage with the high input resistance of a modern multimeter. It also allows you to use a current measurement instead, either with a mechanical VOM or bare meter movement, or with the multimeter. Your multimeter might work better in this mode. It can't hurt to produce a calibration for current too, so you can compare the measurement of voltage and current if something looks weird. (i.e. If you have your doubts about RF upsetting the meter due to an unexpected resonance.)

4 comments.

Attachments

title	type	size
RF Power Table Generator Source in PHP5	text/plain	1.082 kbytes

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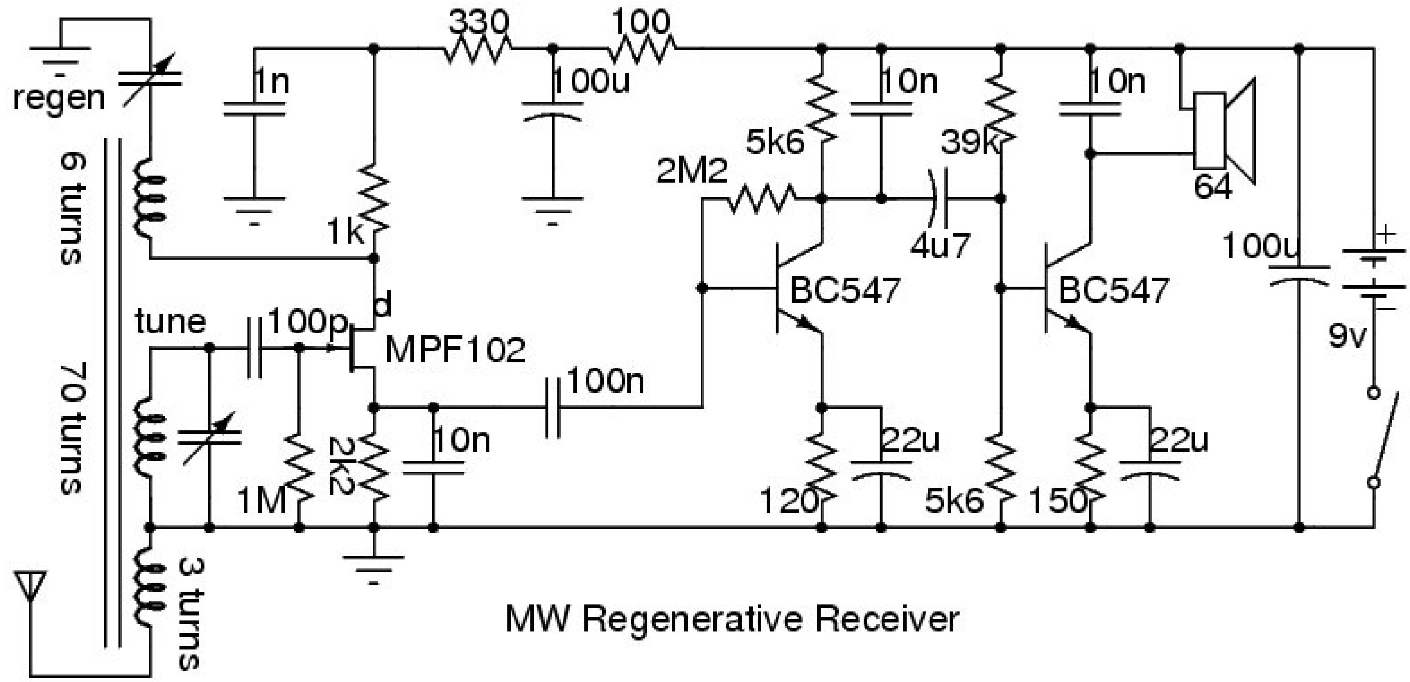
MW Regenerative Receiver

2006-08-06

This radio is based on the Moorabbin Receiver. The Regenerative detector is basically identical, however the audio stage in the original radio is dependant on a transformer that is now quite expensive in Australia. I also believe the gain of the original audio stage is insufficient for comfortable listening with weak signals.



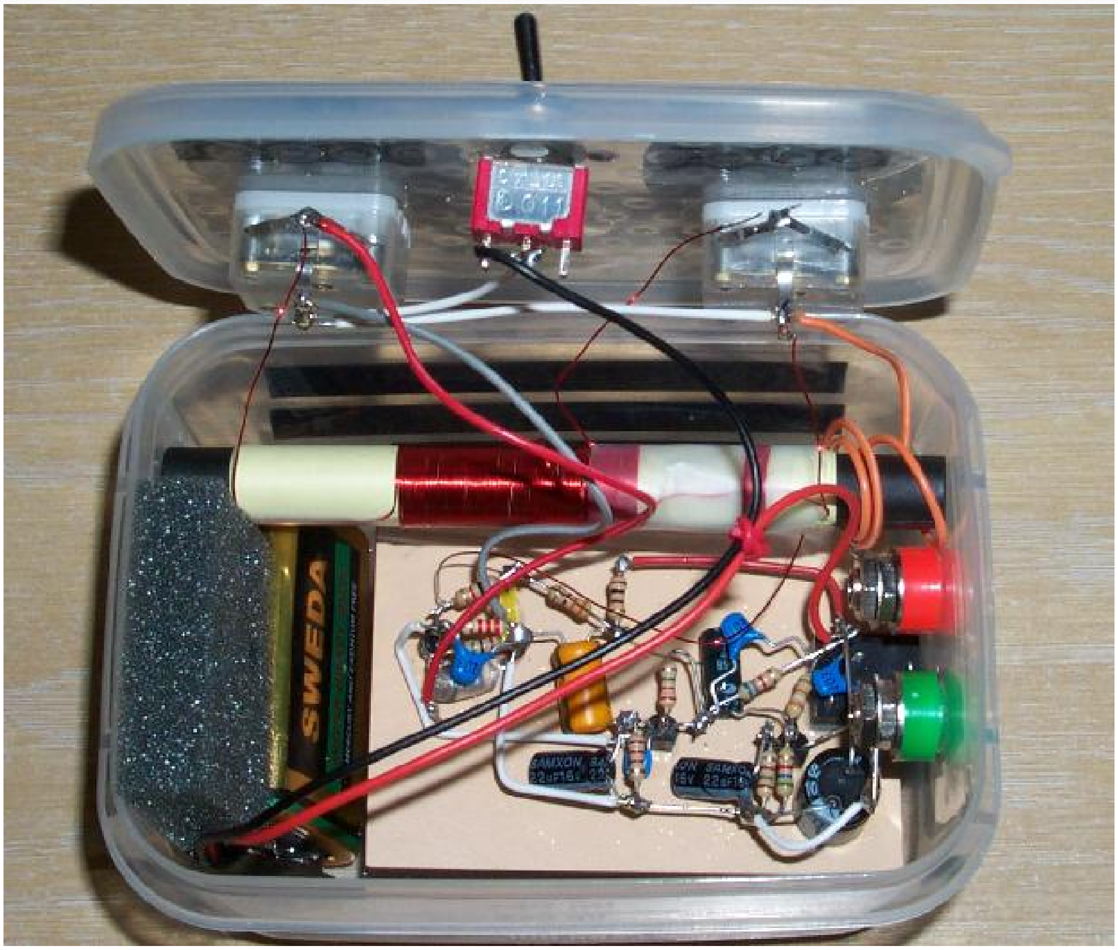
The audio pre-amp stage is biased to 750 uA. It is somewhat noisy. Metal film resistors and a transistor with lower noise and better gain at a lower collector current would perform better. (Try a BC550 or BC549C.) However, it is simple and works quite well. You can increase the 10n capacitor in the collector to roll-off the HF response earlier if you find the audio a little tinny. (Doing so will also kill off much of the noise the stage produces.)

The audio "power-amp" is a simple class A affair, biased to 3.5 mA standing current. The DC passes through the speakers, this might be considered undesirable, but is safe at such a low level. Like all such primitive circuits it suffers from positive-going amplitude distortion as the beta of the device changes with its collector current. I experimented with a current mirror to prevent this, the distortion was almost completely eliminated, but at the expense of two more transistors and more than twice the supply current draw. As this device is powered by a 9V battery and I wanted an extremely simple device I elected to use the simpler output stage. The distortion is quite small at "normal" listening levels and is basically a non-issue.

You might like to use something similar to the audio output stage from the VHF regenerative receiver instead.

The device was built into 250 ml Decor brand Polypropylene kitchen container with a friction-fit lid.

The circuit was built point-to-point on a sample swatch of Formica (the kind you find in hardware stores), superglue was used to glue down the 3.5 mm stereo headphone jack, the transistors, and several capacitors, giving it sufficient rigidity. The ferrite rod (Jaycar's old short one) friction-fits inside the top of the box surprisingly well. The tuning and regeneration control caps, and the power switch are mounted on the removable lid. The headphone jack and its attached Formica board bolts to the box side, with some foam padding under the board, securing it in place. The 9v battery is simple held in place with a small block of foam when the lid is closed.



Two banana jacks form the external antenna connections, this was done almost as an after though, the radio is more than sensitive enough for local listening with just the loopstick - in fact with an external antenna you may need to modify the AF stage to have a volume control, reducing the regeneration to control the audio volume compromises the selectivity, which is especially important when you have strong signals like an external antenna can give.

The completed radio pulls about 4.5 mA and will work fairly well down to less than 6 volts. Your average 9 V battery should run the radio for 48 hours or more. The supply decoupling networks are mandatory if you want good stability with higher impedance supplies (like flat 9 V batteries!). The biasing of the AF stages can be modified to work virtually right down to 1.5 V, but at much less than 4.5 V and performance of the RF stage drops. It is definitely possible to make the radio run of a single alkaline cell, but two or more are easier to work with.

Usage Experience

The radio really needs a true RF AGC for casual listening. It is a good radio for beginners to build, it is easy to get going, simple and fun. However, compared to an equally simple MK484-based circuit, its very unpleasant to use pedestrian mobile. On foot or on a bus the huge variations in signal strength leave you playing the regeneration control. There is a particular spot on George St Sydney that 2BL 702 kHz absolutely blasts in at (right at World Square). I don't know why, perhaps it has something to do with the height of the world square building, it may be resonant?

The radio is completely unshielded. Mobile phone radiation goes straight through the receiver and blasts you in the ears. Its quite painful when someone calls you and the mobile in your pocket starts actively radiating. I suspect some careful filtering of the headphone line would help a lot. However, I've noticed that the amount of RF noise detected changes as you tune the radio, probably the internal wiring being tuned as the main gang capacitance changes. It is extremely annoying and makes the radio basically unusable on the Ferry in the afternoon were lots of people are calling their partners to arrange dinner, etc.

TV transmitters, CFL and RFL bulbs, naval radars, repeaters, computers, in fact just about everything electronic radiates RF that will get into this radio and be detected if you aren't careful. This is however quite interesting, listening to all this RF smog is instructive, if at times a little deafening.

A little shielding would go a long way. Peter Parker warns against using a metal box, however if I built the radio again I'd definitely use a Aluminium box. The loopstick could be placed outside, in a piece of Aluminium pipe with a slot cut in it to form an electrostatic shield, but not a shorted-turn. Alternatively the entire box could be slotted and the loopstick mounted inside.

7 comments.

Attachments

Circuit Diagram Source	application/postscript	18.045 kbytes

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2006-08-06

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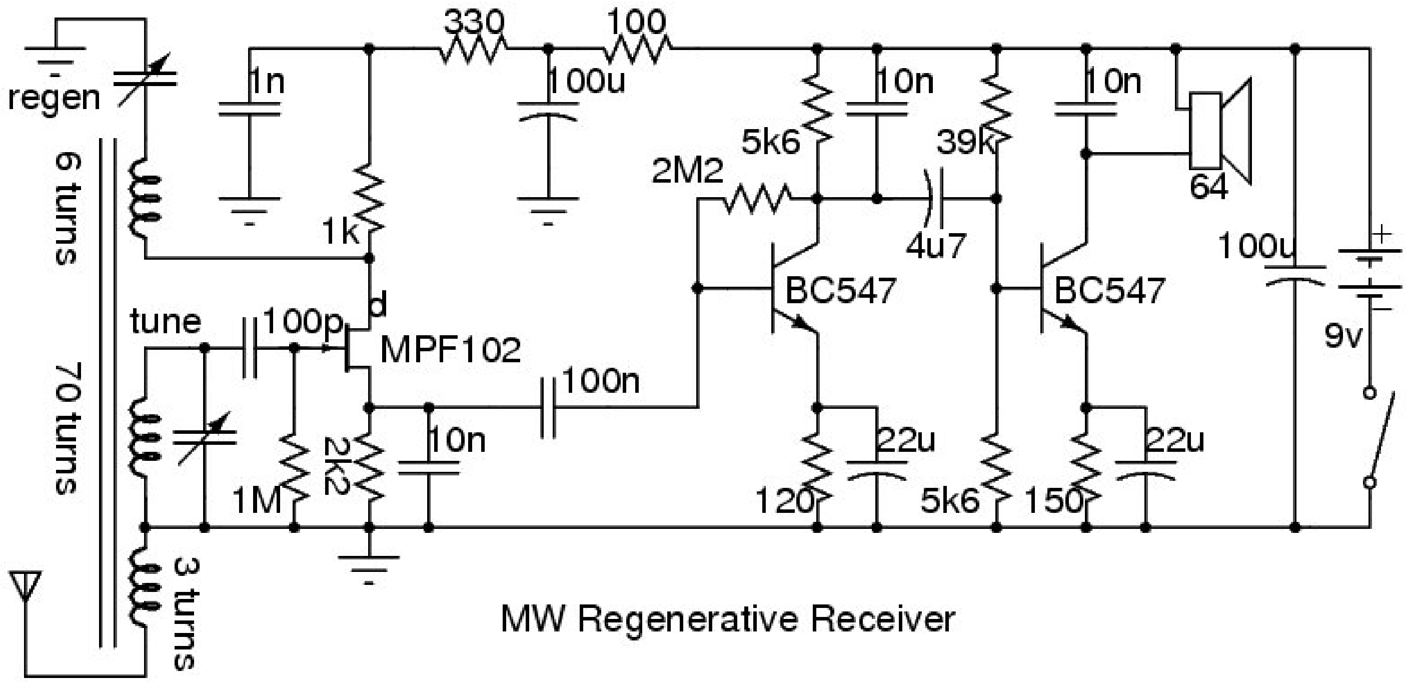

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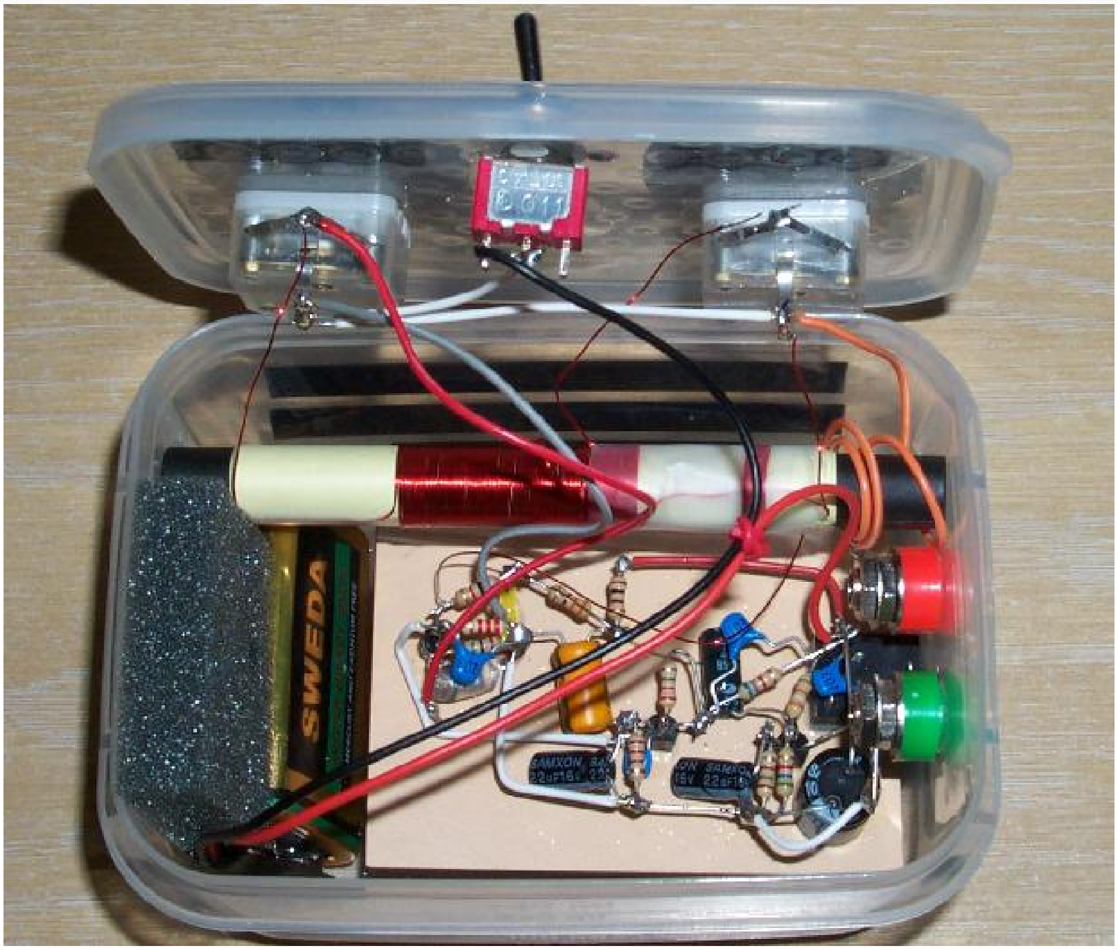
The audio "power-amp" is a simple class A affair, biased to 3.5 mA standing current. The DC passes through the speakers, this might be considered undesirable, but is safe at such a low level. Like all such primitive circuits it suffers from positive-going amplitude distortion as the beta of the device changes with its collector current. I experimented with a current mirror to prevent this, the distortion was almost completely eliminated, but at the expense of two more transistors and more than twice the supply current draw. As this device is powered by a 9V battery and I wanted an extremely simple device I elected to use the simpler output stage. The distortion is quite small at "normal" listening levels and is basically a non-issue.

You might like to use something similar to the audio output stage from the VHF regenerative receiver instead.

The device was built into 250 ml Decor brand Polypropylene kitchen container with a friction-fit lid.

XHTML | CSS | CSS toggle

The circuit was built point-to-point on a sample swatch of Formica (the kind you find in hardware stores), superglue was used to glue down the 3.5 mm stereo headphone jack, the transistors, and several capacitors, giving it sufficient rigidity. The ferrite rod (Jaycar's old short one) friction-fits inside the top of the box surprisingly well. The tuning and regeneration control caps, and the power switch are mounted on the removable lid. The headphone jack and its attached Formica board bolts to the box side, with some foam padding under the board, securing it in place. The 9v battery is simple held in place with a small block of foam when the lid is closed.



Two banana jacks form the external antenna connections, this was done almost as an after though, the radio is more than sensitive enough for local listening with just the loopstick - in fact with an external antenna you may need to modify the AF stage to have a volume control, reducing the regeneration to control the audio volume compromises the selectivity, which is especially important when you have strong signals like an external antenna can give.

 XHTML | CSS | CSS toggle

The completed radio pulls about 4.5 mA and will work fairly well down to less than 6 volts. Your average 9 V battery should run the radio for 48 hours or more. The supply decoupling networks are mandatory if you want good stability with higher impedance supplies (like flat 9 V batteries!). The biasing of the AF stages can be modified to work virtually right down to 1.5 V, but at much less than 4.5 V and performance of the RF stage drops. It is definitely possible to make the radio run of a single alkaline cell, but two or more are easier to work with.

Usage Experience

The radio really needs a true RF AGC for casual listening. It is a good radio for beginners to build, it is easy to get going, simple and fun. However, compared to an equally simple MK484-based circuit, its very unpleasant to use pedestrian mobile. On foot or on a bus the huge variations in signal strength leave you playing the regeneration control. There is a particular spot on George St Sydney that 2BL 702 kHz absolutely blasts in at (right at World Square). I don't know why, perhaps it has something to do with the height of the world square building, it may be resonant?

The radio is completely unshielded. Mobile phone radiation goes straight through the receiver and blasts you in the ears. Its quite painful when someone calls you and the mobile in your pocket starts actively radiating. I suspect some careful filtering of the headphone line would help a lot. However, I've noticed that the amount of RF noise detected changes as you tune the radio, probably the internal wiring being tuned as the main gang capacitance changes. It is extremely annoying and makes the radio basically unusable on the Ferry in the afternoon were lots of people are calling their partners to arrange dinner, etc.

TV transmitters, CFL and RFL bulbs, naval radars, repeaters, computers, in fact just about everything electronic radiates RF that will get into this radio and be detected if you aren't careful. This is however quite interesting, listening to all this RF smog is instructive, if at times a little deafening.

A little shielding would go a long way. Peter Parker warns against using a metal box, however if I built the radio again I'd definitely use a Aluminium box. The loopstick could be placed outside, in a piece of Aluminium pipe with a slot cut in it to form an electrostatic shield, but not a shorted-turn. Alternatively the entire box could be slotted and the loopstick mounted inside.

7 comments.

Attachments

Circuit Diagram Source	application/postscript	18.045 kbytes

 XHTML | CSS | CSS toggle

My Pirate Radio Station

2000-03-25

Some years ago, when I was still in high school, I decided to start a radio station. Just a few watts, 2 CD players, a mic or two, and a mixing desk. Not content with mono operation, I hacked a stereo multiplex, which was probably a mistake as weak signals get noisy faster with stereo. Still, it was a lot of fun, I was never caught, and I learnt a lot from it.

At the time, the call sign 2 HOT FM was not in use in Sydney, neither was the frequency of 94.5 MHz. This I believe is no longer the case. Now days I could probably get a community low-power licence from the ACA, but in those days of the SMA no such provision existed.

The Hardware

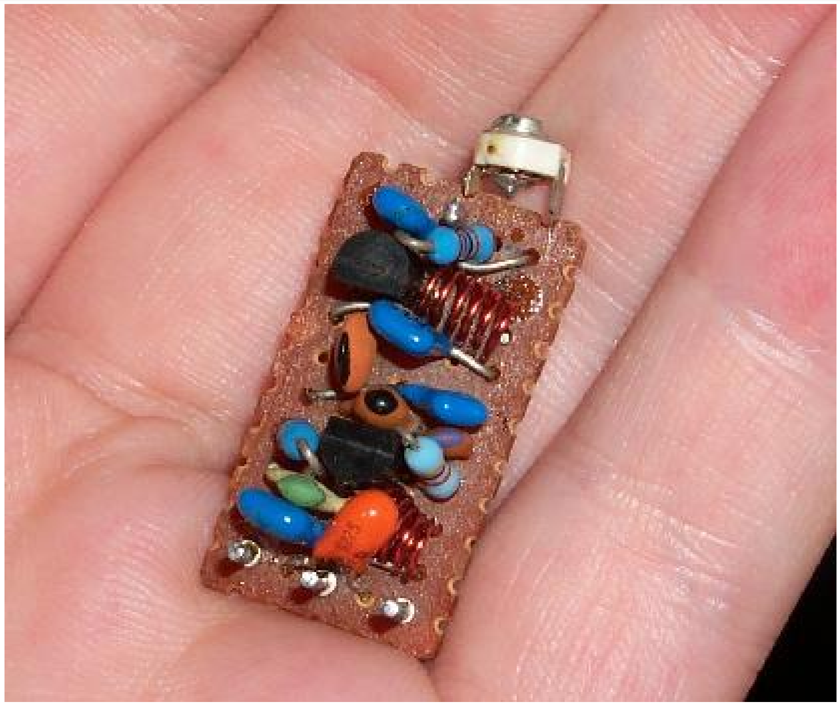
Bits of the transmitter and studio have gone astray over the years. I sold the mixing desk when other interests took my fancy, I believe I got about $200 for it and purchased a CB with the cash. I still have the mics and the RF gear, I used 2 radio mics, one for me, the other for guests.

The exciter was composed of a VCO and buffer, plus a 3 stage amplifier. The VCO has been stripped out for other projects (it worked very well for its simple design, it still rocks actually) the three stage amplifier is show here.

The VCO board connected to the power rails and the MPX signal input (the BNC connector) the buffer output fed into the first stage of the amp.

The 200 mW output of the exciter was fed by coax into a 2 W amp. The output device in this amp was grossly under-speced for the abuse I gave it. I blew them weekly, but at about $3 each it was affordable.

The antenna for the station was a 5/8th wave vertical fed over four 1/4 wave radials. It made a good match to 50 ohms, and was fed using a few metres of RG-58. The physical support for the antenna was a combination of a potted plant, the balcony roof fascia and a length of nylon rope tied to the balcony railing.



The RF system as a whole was terrible, it had to be tuned carefully to avoid parasitics that would otherwise take out TV reception for a block. I've learnt much about RF engineering since then and cringe at how primitive it was, but it did work quite well.

Once it was all tuned up and working the station was heard for several kilometres at full quieting. The fringe zone extended across most of the metro area. My QTH is on the south side of a hill, directly over water, VHF DX heaven, at least towards the south.

What We Played

Well, we are talking about the 90s, so, 90s music.

I can't remember what our exact programming was, but every Friday I would invite anyone I could (mic shy or not) over as guests for the broadcasts. This must have been quite amusing to listen to, and probably refreshing compared to the usual dribble commercial stations air on Fridays. I still have at least one analogue tape recoding of "The DJ Crew" sessions, I should digitize it before analogue technology disappears completely.

We were far from professional, but a great time was had by all. After a few months we even had a phone patch going (even more laws broken!), which became a feature of the Friday programs.

Somewhere along the way I got a girlfriend (perhaps the radio station helped a bit with that! :), got into CB radio, and had to attempt to study for the HSC. The radio station got less and less attention, and fell into disrepair. The Fridays stopped and it was largely forgotten, until I dug out the hardware and took some photos for this page.

9 comments.

Nano-Henry Inductance Meter

2007-03-04

Desiring a simple way to quickly measure inductances in the 10s and 100s of nanohenry for VHF work, I was inspired to build a direct-reading meter like Drew Diamond VK3XU's design "Nano-L" Inductance 'Bridge' for Small Coils. The circuit is published in Volume 2 of his excellent series of books "Radio Projects for the Amateur". I highly recommend you purchase all three volumes, they are great books, I picked up my copies from the recent Wyong Field Day. They can be obtained through the WIA.

I don't know why he calls it a bridge, it is rather a resonance meter, but the name probably comes from its relation to his other true-bridge inductance meter for micro-Henry coils. My implementation is only very slightly different to Drew's, and functions in exactly the same manner. I use a 44.7 MHz TTL oscillator package, as I had some in the junk box. (I actually started out with 80 MHz, but it proved too high for the range of inductances I wanted to measure, with the Lx connection shorted with a piece of brass shim I could peak the meter about middle of the range and a 2" hairpin was beyond its measurement range.)

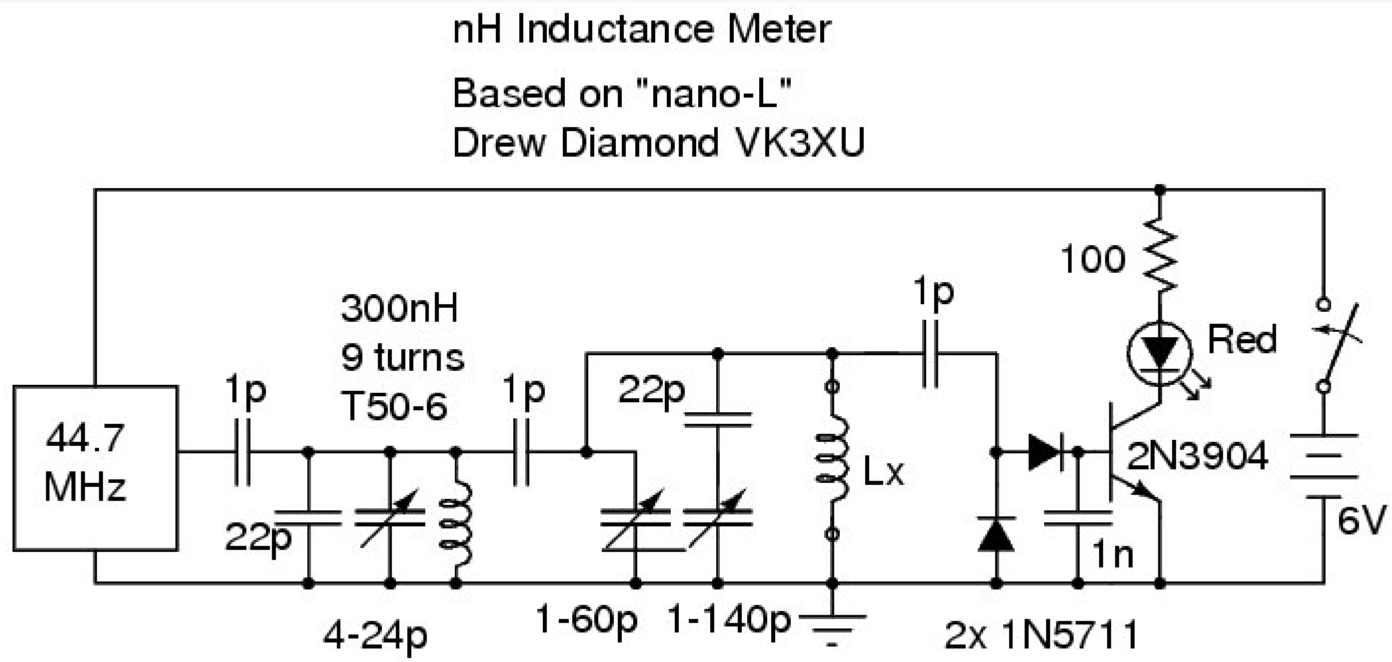
I also used a "polyvaricon" style capacitor, lacking a suitable air-spaced gang. The detector is identical, and the clean-up resonator values picked for the lower design frequency. I used a spring-loaded speaker terminal block for the Lx connector. I was concerned this would limit its range, but in practice is has proven quite usable, and much more expedient than binding posts.

The circuit is constructed on a piece of unetched PCB board and mounted in a die-cast Aluminium box which came painted glossy black. Four AA cells provide the power supply, the TTL oscillator can is run at the full 6 volts, there is no dropper diode to keep it within spec, it gets warm but doesn't seem to mind.

The Circuit

The case is dominated by the batteries, inside there is much free space. The Lx hot-side connection is made with a fragment of PCB board to minimise the stray inductance and improve the instrument's minimum inductance capability.


Energizer



Usage

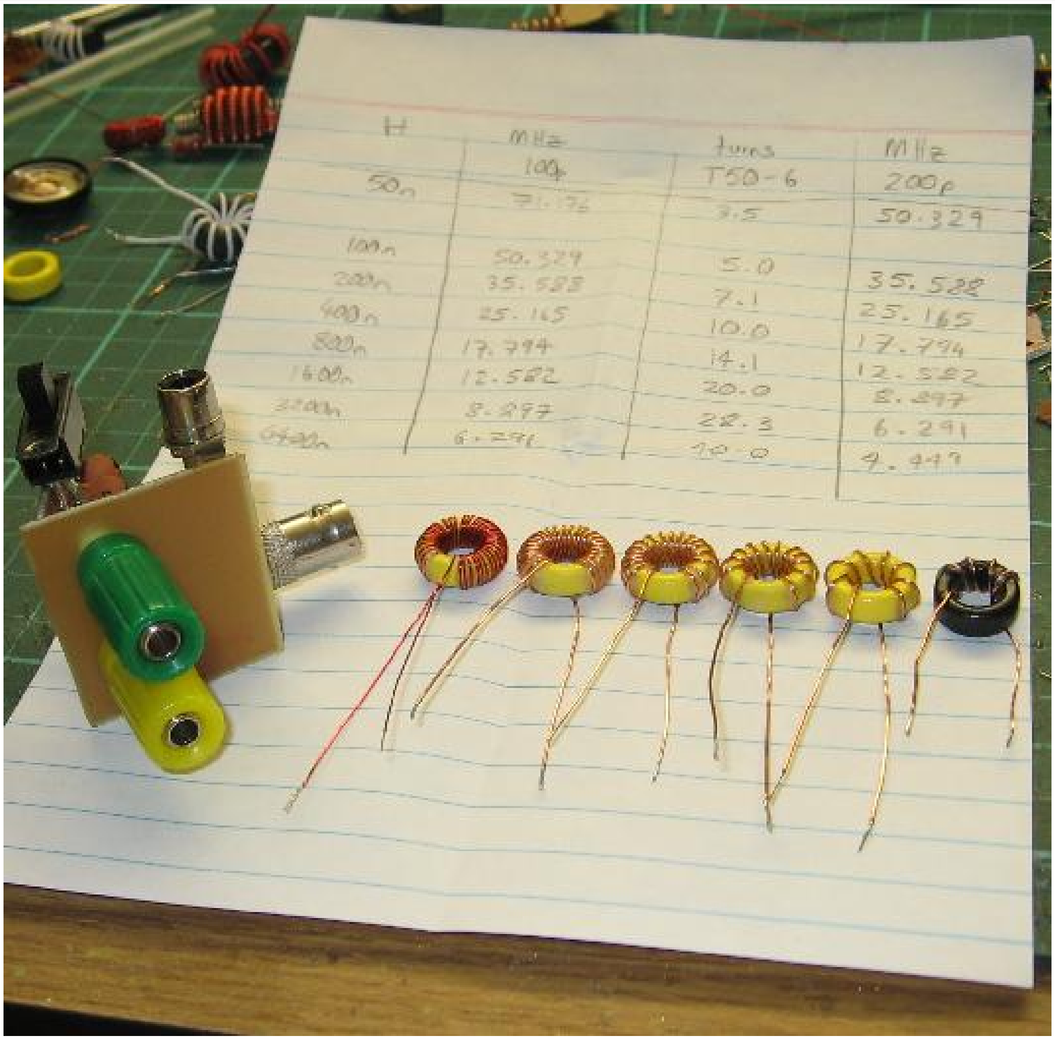
To use; one connects the inductor to me measured, switches on the unit and sweeps the knob searching for peak brightness of the red LED. The tuning is fairly sharp with moderate-Q inductors, and the peak is generally very obvious, a few degrees off the peak the LED will be completely extinguished.

Calibration

Building the unit is quite easy, but to make it a practical instrument it must be calibrated. You can probably use 5% chokes for the top of the range, but commercial inductors towards the bottom of its range are rare or SMD-only devices.

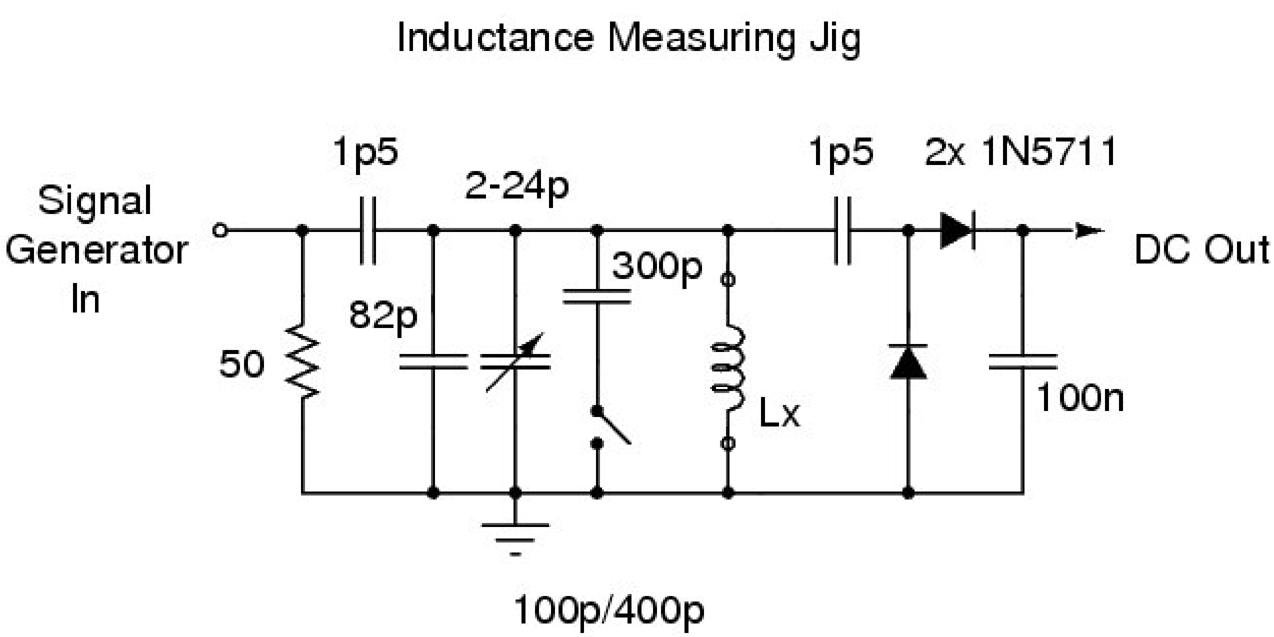
To calibrate mine I decided to construct a series of calibration inductors of fairly high accuracy, a challenge that exceeds that of building the unit by an order of magnitude!

Having 100p capacitors of fairly high accuracy and stability, I sat down with my LC resonance calculator and came up with resonant frequencies for a geometric series of inductors, resonated with 100p and 400p. As I can measure frequency and capacitance to within about 1% this gave me a way to trim my inductors to the desired values with accuracy beyond what the meter needed.



I choose T50-6 cores for the larger inductance values as they offer the best stability/Q/price trade off. The material is suitable for the VHF test frequency, and has a fairly low thermal coefficient. Tx-7 (white) cores are better but much more expensive - I save them for VFOs. A T50-10 core was used for 200 nH, but I may replace this with a air-core inductor as I am unimpressed with its mechanical stability. Values below 200 nH were all air-core, wound with stiff tinned copper wire. All coils were dipped in wax once trimmed to stabilise them. Some experimentation was performed with enamelled wire on soda straws, but the stability was inferior. Repeatability of sub-150 nH inductors is somewhat challenging, even when waxed to a core and the lead length carefully controlled.

The testing jig in the picture above was specially constructed for the calibration exercise. It allows a trimmed 100p or 400p to be switched across the inductor under test. The signal generator is used as the frequency source, measured with a high-resolution frequency counter than has had its reference zero-beaten against WWVH recently. A CRO or VOM is used to detect resonance, measuring the DC voltage generated by a charge pump. In principle it works a lot like the meter itself, except the capacitance is fixed and the frequency variable.



To use, one hooks it up to the detector and signal generator, then measures the capacitance seen across the Lx terminals while trimming it to precisely 100 pF or 400 pF. The capacitance meter is then exchanged for the inductor under test and the signal generator swept to find the resonance peak. Note that in some situations rearranging the circuit to use series resonance would be preferable. One would then tune for a null, which is

generally a better proposition anyway, but I used parallel resonance for all my inductors and had little problem achieving high repeatability.

How precise is all this? I am not sure, but I estimate at least 5% with careful use, if not better, as long as you are well below the self-resonant frequency of the inductors.

The testing jig is a useful gadget in its own right, and is usable across a wide range of inductances, it can't hurt to build something similar yourself. Use NP0 capacitors of good quality and their values should be pretty close, even without the ability to measure capacitance. The distributed capacitance of my particular jig was 4.6 pF, so even untrimmed it is still fairly accurate.

1 comment.

Attachments

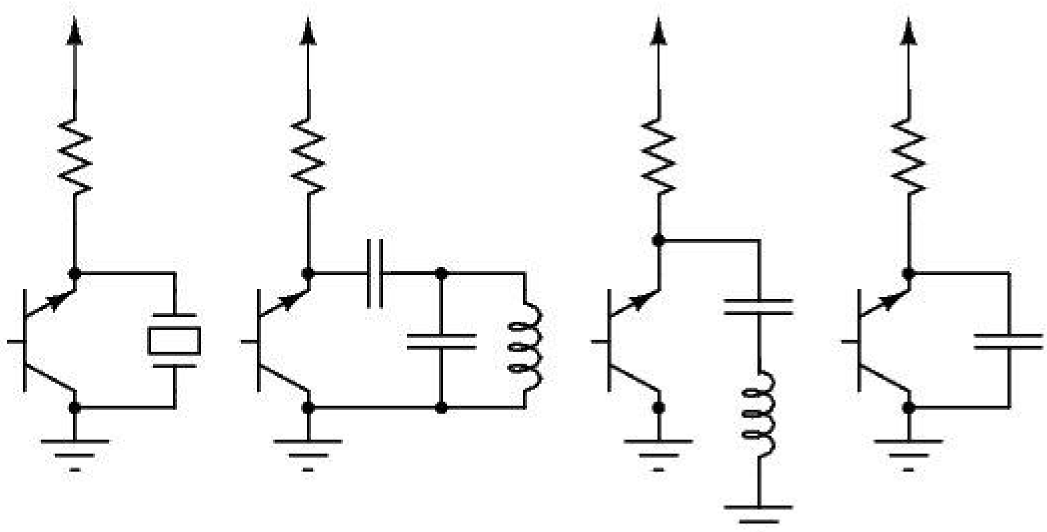
title	type	size
Inductance Measuring Jig Circuit Source	application/postscript	12.981 kbytes
Inductance Meter Circuit Source	application/postscript	15.142 kbytes

Negistor Applications

2008-02-29

The "Negistor" is a favourite toy of the Free-Energy Freaks. (More charitably known as the Over-unity Experimenters) Unfortunately most over-unity experimenters don't seem to grasp the conceptual difference between power, voltage and current. Neither do many seem to understand that average power is an integral and most test equipment is not true RMS, and that even true RMS multimeters have bandwidth limitations. Build something that will indefinitely deliver more DC power than what it receives from all sources and I'll start taking you seriously...

Anyway, enough OU-bashing, the negistor is a common NPN transistor, biased with its emitter more positive than its collector and the base open-circuit. Most signal transistors break down at about 8 volts in this mode and in the avalanche region exhibit some negative resistance. Negative resistance is nothing magical of course, just a non-monotonic region in the device transfer function, but it lets us build somewhat exotic-looking oscillators.

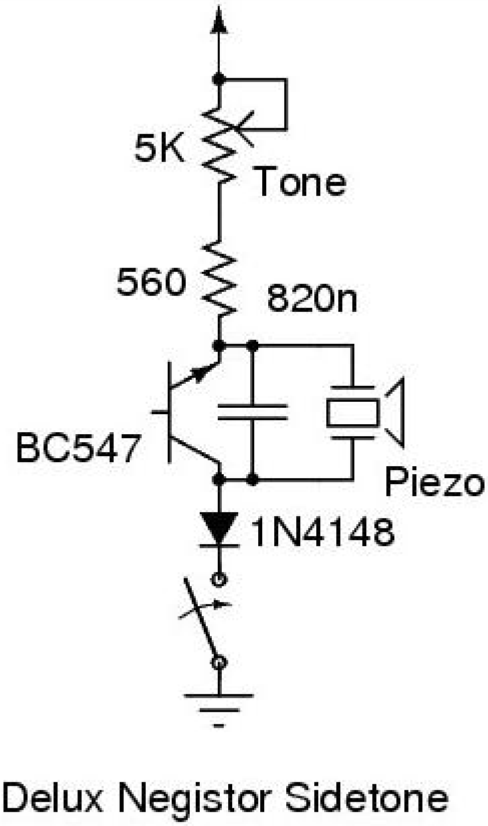


Negistor Oscillators

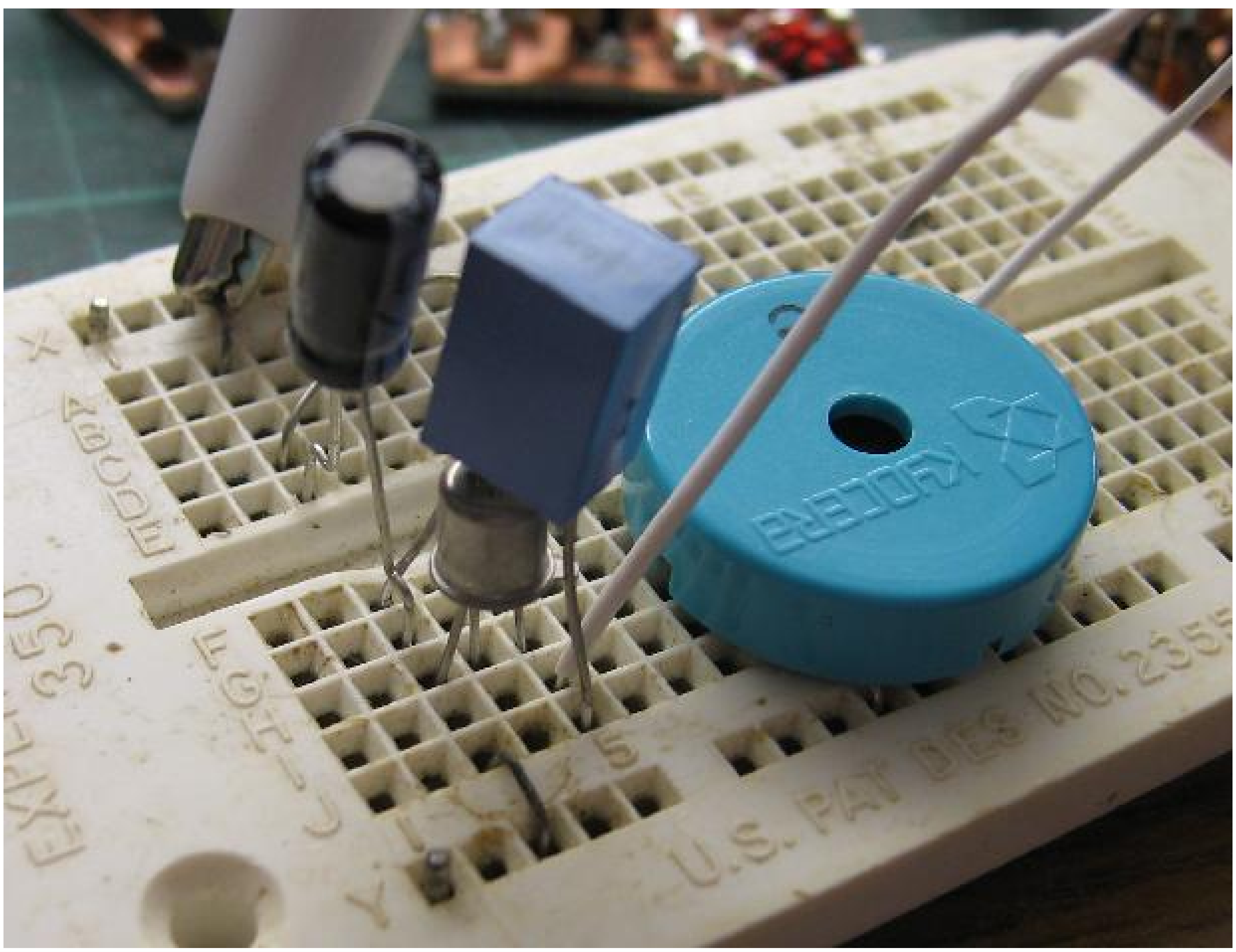
By placing a tank across the negistor, oscillations up to about 1-2 MHz can be achieved. Even just placing a capacitance across the device will cause oscillations, the circuit functioning somewhat like a NE-2 Neon relaxation oscillator.

PY2OHH utilises this curious circuit as a BFO oscillator! This ingenious application inspired my interest in the circuit, especially after I realised it could produce pretty linear sawtooth ramps. I was hoping to use it as an minimal component external quench oscillator, but the output is very small in amplitude and a unijunction oscillator is better suited. With amplification it could be used as a simple sweep generator instead of a unijunction, NE555 or Op-Amp circuit.

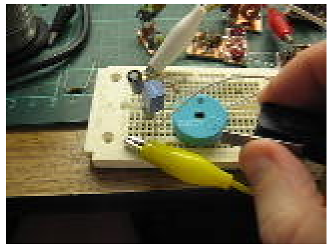
The most immediate application I could think of is a simple sidetone oscillator for QRP rigs. Most QRP rigs are powered from 12 Volts, so the supply voltage is sufficient, and the resulting circuit has quite a low parts count. A piezo squeaker is used to actually make the noise, and just three other components are needed, four if you include a keyline diode and maybe five for a shaping capacitor to soften the edges.



You could add a 1k pot for a volume control if you wanted. You might like to pipe the sidetone out via the RX AF path instead of via a piezo. In which case you can just capacitive couple it into the AF amp input.



Anyway, it works. Its simple, if kinda exotic. Possibly the weirdest code practice oscillator you might like to build too.



Demo Video
(741.605 kbytes)

Notes

- Try using the piezo capacitance alone for optimum 3-component minimalism.
- Base voltage affects its properties, one negistor oscillator can FM another... Siren applications?
- Some transistors work much better than others. I found an old BC109 that worked quite well.
- Can you make a regenerative receiver by putting a variable +ve resistance in the tank and tuning it for near-zero affective resistance?

9 comments.

Attachments

title	type	size
Negistor Circuits Source	application/postscript	14.431 kbytes

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Neon Flasher

2003-02-14

OK, there is nothing special about flashing a neon, but this little inverter will run from as little as 1.2V (a NiCd or NiMH cell).

The circuit is based on the Joule Thief circuit which is credited to Z. Kaparnik on that site. The circuit is a simple oscillator, which in the case of the Joule Thief has sufficiently high voltage spikes at the collector when running from less than 1.5V to forward bias a LED. In the practical circuit I built to test the idea (very neat I might add!), the spikes are about 35V peak at 70kHz into an open circuit. Add the LED and the frequency drops to about 40kHz and the voltage is clamped to the drop of the LED, with a duty cycle of about 75%.

For the neon flasher I have used the same Hartley oscillator configuration, but instead wound it on a xenon flash lamp trigger transformer to facilitate a voltage step-up to the 70-90V needed to ionize the neon. The raw AC output of the transformer will light the neon quite well from a 3V supply, but adding a rectifier and storage capacitor gives bright flashes from 1.2V or less.

The trigger transformer is the model available from Jaycar Electronics, it has the secondary wound on the ferrite core first, the primary is wound over that with thicker wire. It is a simple matter to remove the primary winding and wind 400mm of bifilar 0.2mm winding wire onto the core to make the new primary and feedback windings (take about 800-1000mm of wire, halve it, twist it up with a drill, and wind that, then separate out each filament with a continuity tester). It isn't really practical to save and re-use the primary, or even leave it in its auto-transformer configuration, unless you redesign the oscillator to have the primary in the emitter (probably worth a try some day).

While not really suited to the frequency the 1N4004 works almost as well as an 'ultra-fast' device of the same current rating, the difference isn't worth being concerned about, I measured it at 2% percent (which was surprising). Picking a neon that ionizes at a low voltage allows the circuit to operate usefully to very low input voltages. It will continue to oscillate to at least 600mV, but won't produce enough voltage to fire a neon below about 1V. I probably wound too many turns on the primary, using a few less could extend the operational

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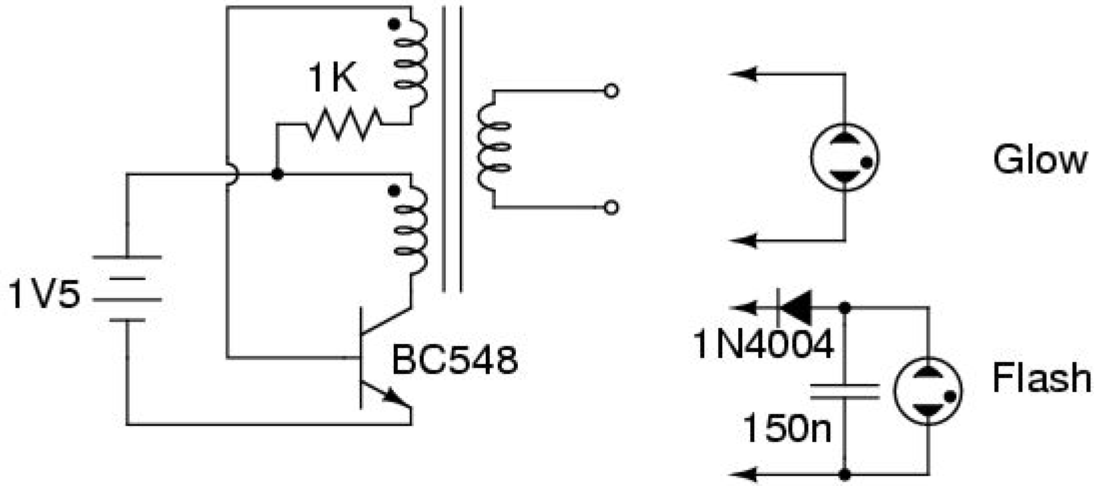
voltage lower, but would make the efficiency even worse. The whole transformer is 'wrong', but very easy to work with.



Super Simple Neon Inverter

My prototype unit pulls 33mA from 1.5V (about 50mW), charging the output capacitor to 82V before the neon fires. That means with each flash about 500uJ is delivered to the neon gas per shot, at 4Hz flashing rate, that places the efficiency at a woeful 4%. Less than 1mW is lost in the bias resistor, the bulk of the losses are in the transformer magnetizing current and the capacitive load of the diode and storage cap series combination across the high impedance secondary. A resistor to control the charging rate might help with those losses, as might an RF rated rectifier with lower reverse capacitance and a fast response time. I am not sure if decoupling capacitors would help, but the problem is fundamental, the transformer and rectifier are too lossy because they are operating at around 200kHz.

There is no discharge resistor across the cap. I tried a 10M unit, but it loaded the circuit too much to flash at 1.2V. Instead I just potted the entire device in epoxy. To display how poorly designed and feeble the transformer output is, you can place your finger on the epoxy over the hot side of the transformer near the diode and the extra capacitance will drop the flash rate. If your unit seems even more pathetically inefficient than mine, try reversing the diode, the drive is unipolar and far from square so you should pick the best half of the cycle for charging and leave the least for the losses.

Although I've made it sound really bad, it works well, even if it isn't very efficient. In glow mode it is quite a bit more efficient, the RF output ionizing the neon easily, but the primary still has too few turns and a very large magnetization current. Winding your own transformer but keeping the circuit the same you could achieve much more efficiency, but the wire would be very thin and take considerable effort to wind without a machine.

1 comment.

Attachments

title	type	size
circuit postscript source	application/postscript	12.795 kbytes

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Home Twitter YouTube Calculators

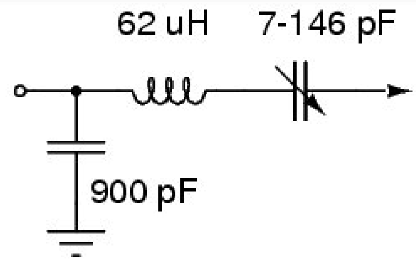
New Beacon Antenna

2008-07-13

Its been a while coming, but I've been battling the winter flu so the antenna project has dragged on a lot longer than I wanted. Part of the delay was waiting for thick magnet wire to arrive from OBA they were doing a stock take and my order took a few days to process. I was happy enough with that as at the time I was in bed crook anyway.

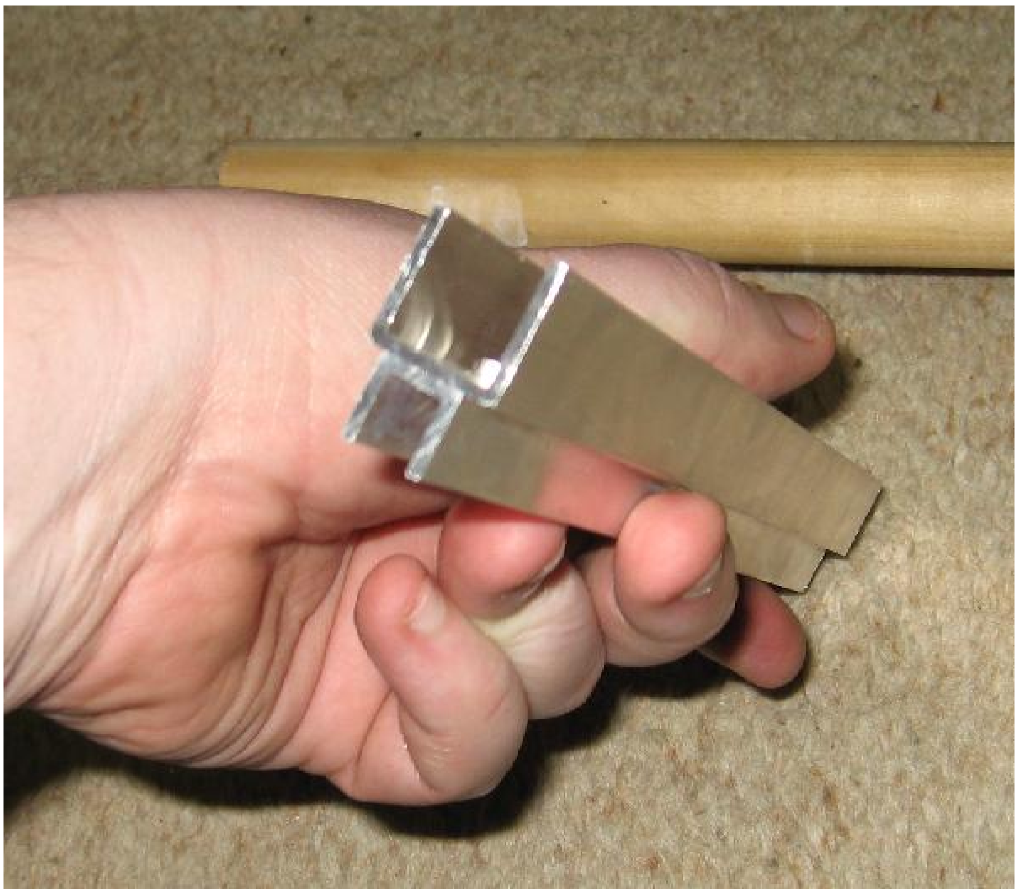
Once I felt better and had collected all the materials, it was a relatively quick exercise to assemble the new antenna. A three meter section of the 15 mm OD Aluminium tube was used for the radiator. A quick lash in the selected position allowed me to measure the capacitance it saw against the balcony railing. The figure was a surprisingly high 34 pF... Some quick calculations said I needed about 60 uH for a base loading coil with enough room to play with assuming my measurements where a bit off. I temporarily tuned out the antenna capacitance using the previous loading inductor and my C-jig, then using my impedance bridge and R-jig I was able to measure the pure antenna resistance at 22 Ohms. This figure was rather disappointing, but it turned out to be a bit too large, the result of significant coupling to my body in the vicinity of the tests.

Some maths, coil winding and bench testing later I had a 62 uH base load inductor, ~900 pF of matching shunt capacitance and a polyvaricon to match the transmitter into the antenna. It turned out the polyvaricons I recently purchased had sufficient voltage rating for this application, unlike the one I previously cooked in the C-jig. The loading inductor was close-wound despite this giving is a somewhat reduced Q. When the coil losses were compared to the grounding system losses the improvement in Q at the expense of coil volume was not really worth it. The coil is already quite large ~2" ID, 5" long and has a pretty good Q, the SRF is beyond 12 MHz.

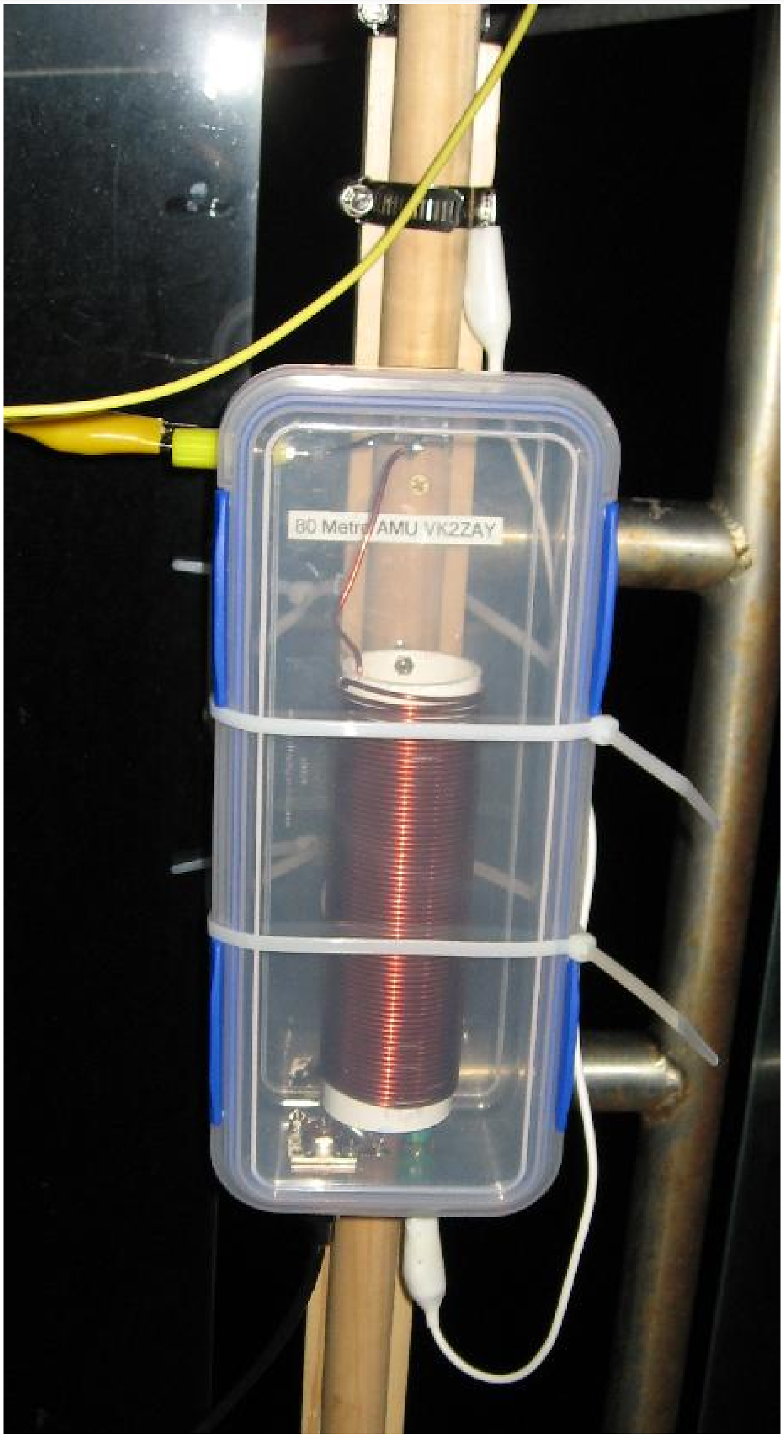


Antenna Matching Network

A 25 mm dowel and a piece of scrap timber gave me the stand-off and mast for attaching the antenna to the balcony railing. A piece of PVC tubing over the timber provided the base insulator (not shown). To hold the radiator square against the mast I bolted two appropriately sized pieces of channel section back to back with stainless hardware and held the works together with stainless steel hose clamps. This was surprisingly effective and quite easy to assemble with no special tools. Hose clamps also held the mast/stand-off to the balcony railing and facilitated the ground connection.



The matching network was boxed up and lashed to the mast with cable ties. This is not intended to be its permanent fixture, but it seems fine as the matching box is fairly light. If I replaced the cable ties with black UV resistant units it might be better. No doubt the matching box itself will suffer from UV exposure, it is just a Sistema Plastics Klip It Meat Keeper box designed for cold-cuts storage. Cabling from the matching box to the antenna is currently just alligator clip leads, these will probably fall apart in the salt air within a week or two and will be replaced with stainless/Aluminium to copper transitions terminated in banana plugs, all suitably weather proofed.



Connection to the transmitter is made with a few metres of RG-58 coax, the transmitter and switchmode PSU being double bagged and placed under the eaves out of the direct weather. I added a "Tune/Operate" switch to the beacon TX which gives a choice between keyed CW or just solid carrier. This is very useful for tuning up the antenna network. There is some interaction between my body and the antenna, generally I need "overtune" a touch, back off and crouch to minimise my capacitive loading and observe the match. Some iteration finds a good setting of the polyvaricon. Initially I used the impedance bridge, but I've found a NE-2 bulb hanging off one of the hose clamps on the radiator works very well for tuning for maximum smoke (which very nearly coincides with 50 Ohms resistive input impedance to the matching box).

10 comments.

Attachments

title	type	size
AMU Circuit Diagram Source	application/postscript	10.604 kbytes

Parent article: 80 Metre CW Beacon.

Alan's Lab

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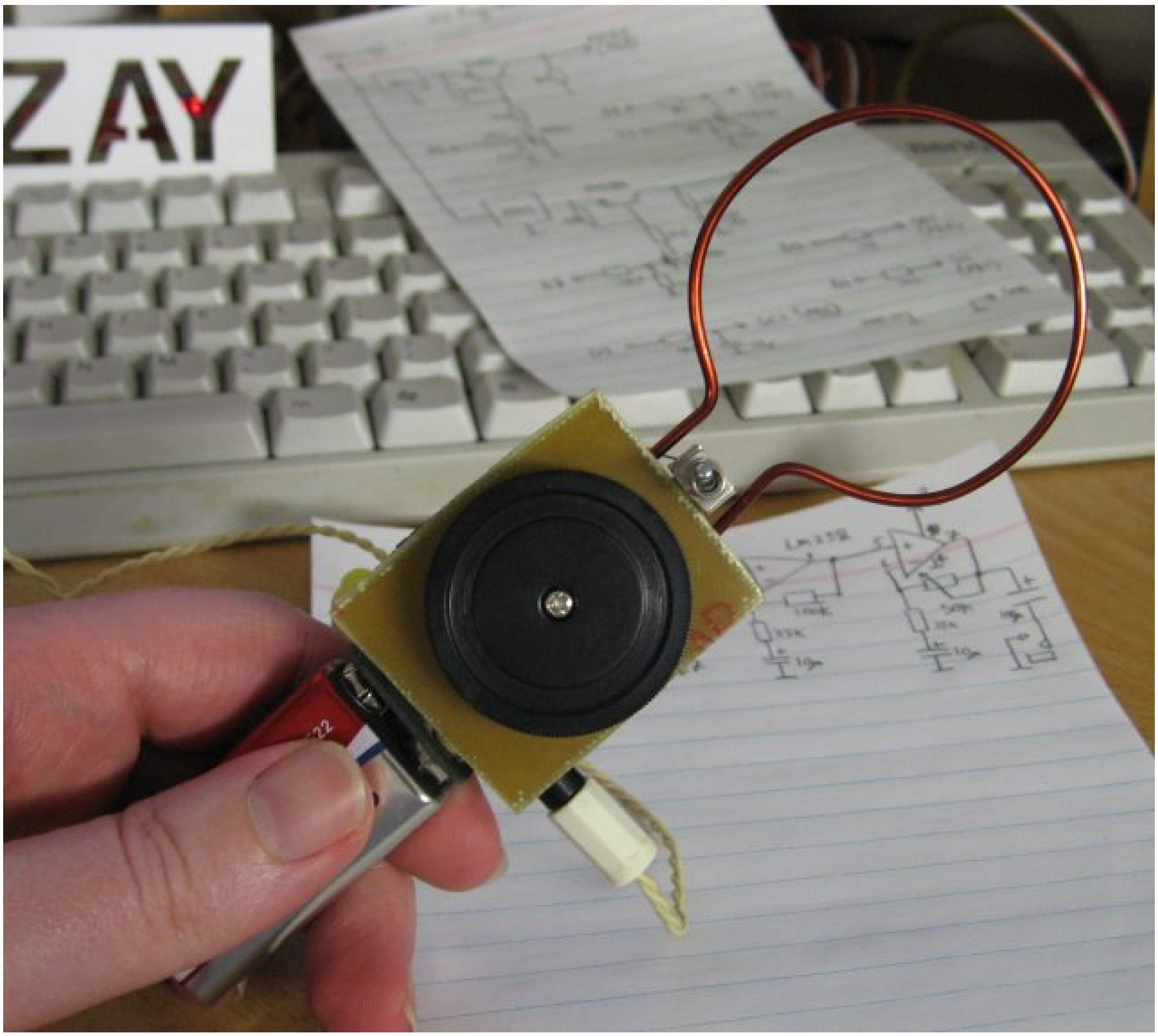
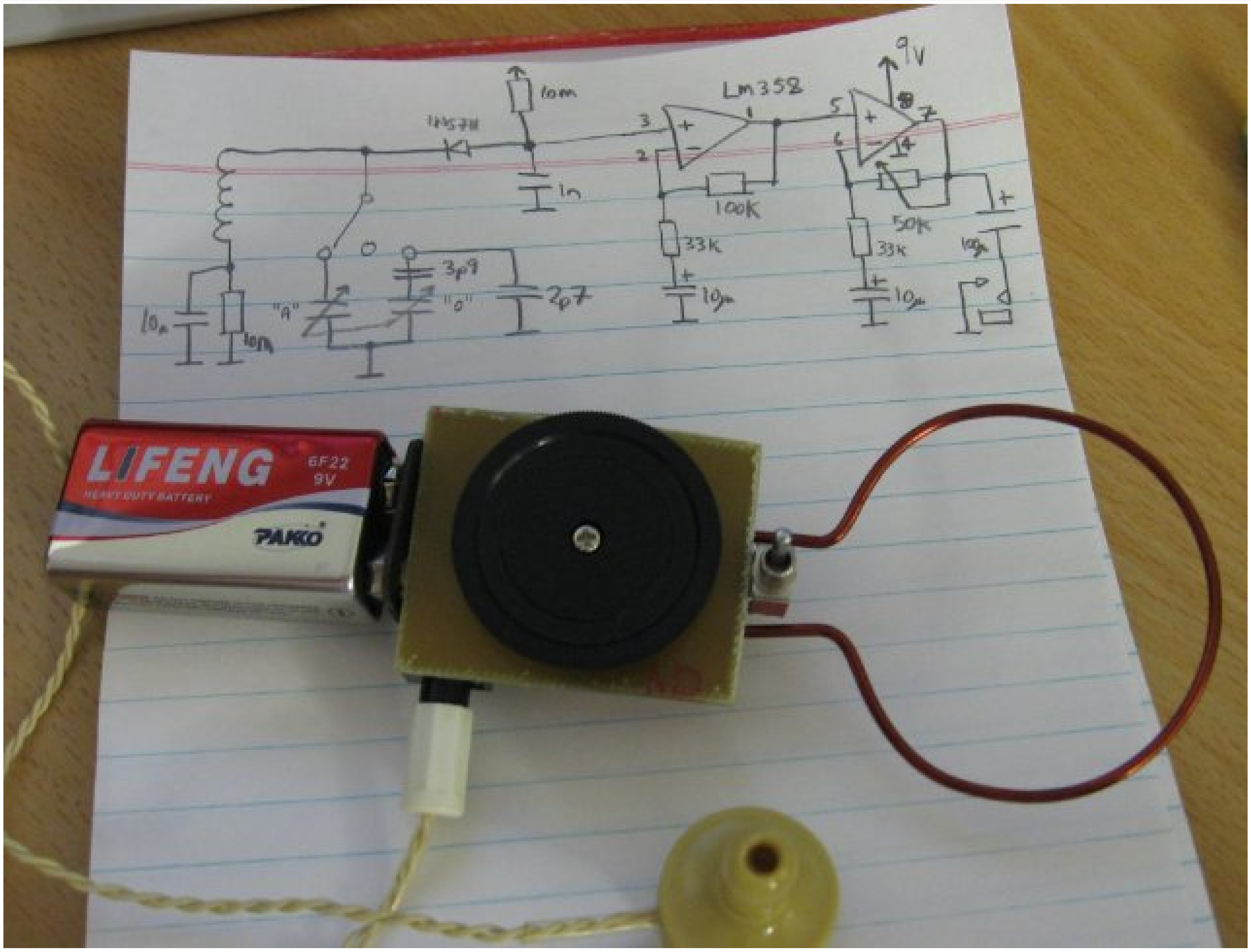
Non-Emissive Air-Band Receiver (Implementation & Use)

2010-06-11

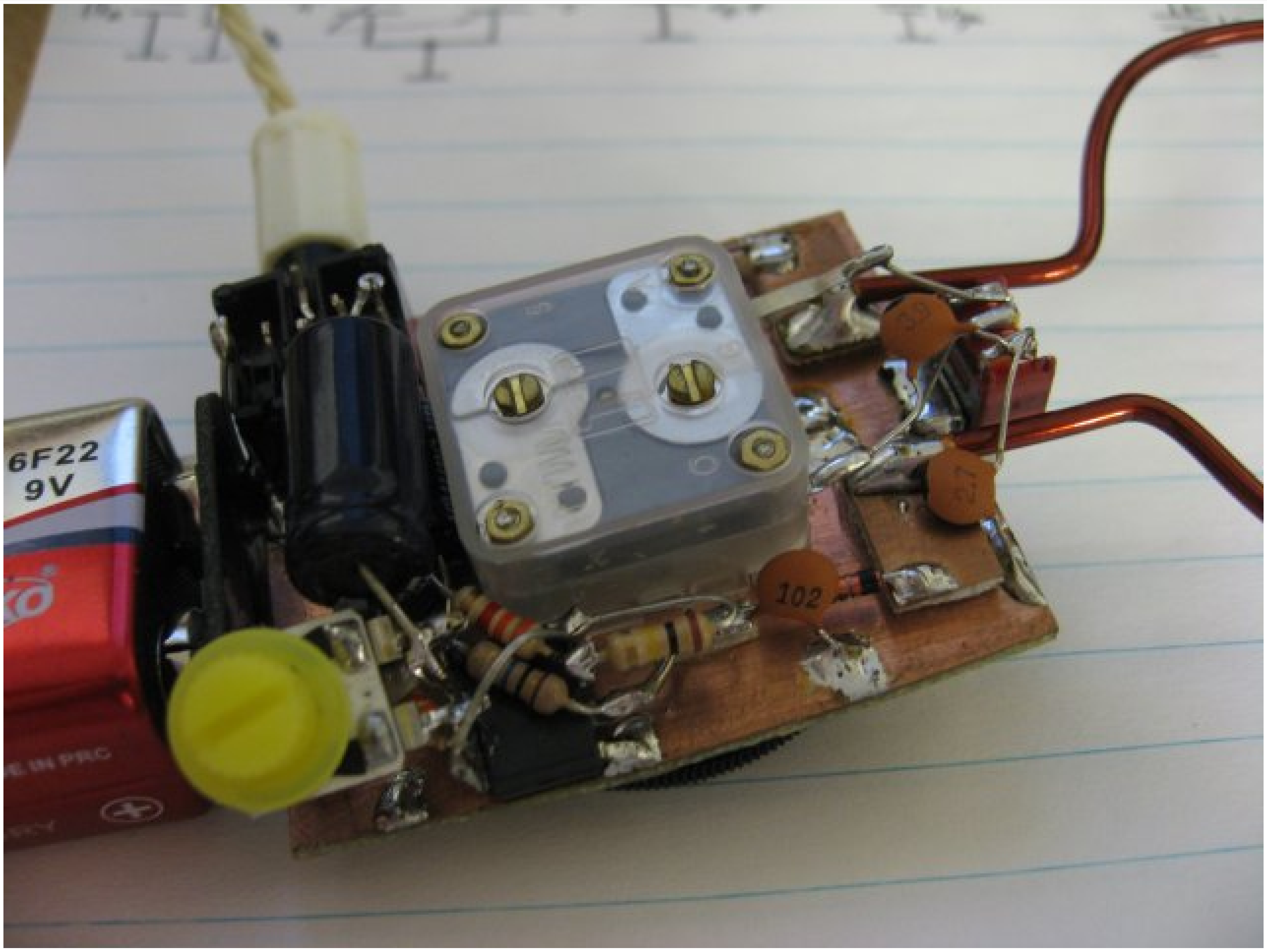
I threw this receiver together the day before I left for the United States for a months holiday. It is anything but physically elegant, I half expected it to be confiscated by TSA so I did not spend a lot of time on making it pretty.



The circuit is only superficially different to Charles Wenzel's original design. The major departure from Charles' implementation is the use of the main tank inductor as a loop antenna. A stiff piece of ECW is used to create a 50 mm diameter loop, which is both the receiver antenna and the tuned circuit providing the receiver selectivity. In this way it is somewhat similar to my VHF Wavemeter, but the detector circuit is an AF amplifier and the cross-section of the loop is larger to intercept more RF.



Construction centred around the physical bulk of the polyvaricon tuning capacitor, the loop antenna, and the 9 volt battery power supply. The small centre-off switch selects between bands. One band tunes 32.7 - 126 MHz, the other a narrow range of interest in the Air Band, 121 - 133 MHz. In the centre "off" position the loop acts as a short-range magnetic probe for RF with sensitivity increasing rapidly with frequency (the loop inductance is quite small) - in this mode the device is essentially Charles' Amazing All Band Receiver.



The receiver selectivity is so poor tuning can be quite imprecise. This is actually a benefit in practical use, allowing sloppy tuning while searching for signals. In practice the only signals you hear on board an aircraft are transmissions from the aircraft which hop around in frequency. I did on occasion hear other aircraft on the ground or the tower, but the signals were quite weak, the receiver is not very sensitive. That said, on the broad tuning band I can hear FM and TV stations quite clearly at home - a high signal area.

In-Flight Experience

On the international flight from Australia to the US I heard very little. Once over the pacific VHF is basically not used until shortly before landfall in the US. I did hear the push-back, taxi, and take-off clearance acknowledgements, and once in the air a few other transmissions before leaving Sydney's controlled airspace. Similarly on arrival in the US I heard the pilot contact the approach controller, get talked down through the busy LAX airspace and once landed heard the instructions to wait for towing to the gate. Sydney security didn't even bat an eyelid about the device, it just went straight through the carry on x-ray scanner. On the aircraft the crew and passengers ignored it, but I didn't exactly wave it around nor try to hide it either.

The domestic flight from LAX to Boston was more interesting. Over land the pilot is continously contacting different airspace controllers and moves around in frequency quite a lot. We had to fly around a massive storm system and deep into Canadian airspace, changing flight level many times, it is quite interesting hearing the pilot request course and level changes to avoid storms or take advantage of jet streams. It is an extra window on the whole flight experience. Once upon a time there was an in-flight entertainment channel for this, but AFAIK no airline has this option any longer? Generally tuning coarsely to the "top" and "bottom" ends of the narrow range was sufficient to keep up with the pilot, even if you didn't hear what frequency he was acknowledging the QSY to. If the signal became weak (indicating the TX frequency was at the other end of the band from where I was tuned) you just racked the polyvaricon to the other end of the band. Yep, the selectivity is that hopeless you can hear the transmissions (weakly) even if completely mis-tuned by 10 MHz. Once again security couldn't care less about the unit. I had purchased a small (Pelican 1030) hard-shell case for the device in LA, bright yellow like a Civil Defence radiation meter. One humorous moment was hearing the pilot argue with the tower about how much fuel he was wasting while delayed on take-off.

On the flight back from Boston to LAX TSA did flag the device. I aroused their suspicion somewhat because I had a 800 ml dewer of drinking water with me that I forgot to tip out until right at the check-point. I also suspect

TSA lady asked me a few questions, I said I was an amateur radio operator, etc. When asked why I built such a device I answered simply "I am a geek." Apparently a good answer, I was allowed to continue on my way with my receiver. The in-flight reception was a little poorer this time, some broadband RFI from the entertainment system was more audible and the air band signal was a bit weaker in the particular seat I was in - still quite usable though.

The international flight from LAX to SYD was quite similar to the initial flight. No security dramas and no traffic once out over the pacific. The periodic data-bursts I could hear on all flights was somewhat louder on this flight. I assume this is ACARS? Oddly enough the voice transmissions were much weaker, perhaps they use different antennas and I was near a node in the RF pattern inside the airframe that the voice TRX antenna excites?

So, in summary a bit of geeky fun and no security dramas despite a quite conspicuous looking, clearly home-made device.

18 comments.

Parent article: Non-Emissive Airband Receiver.

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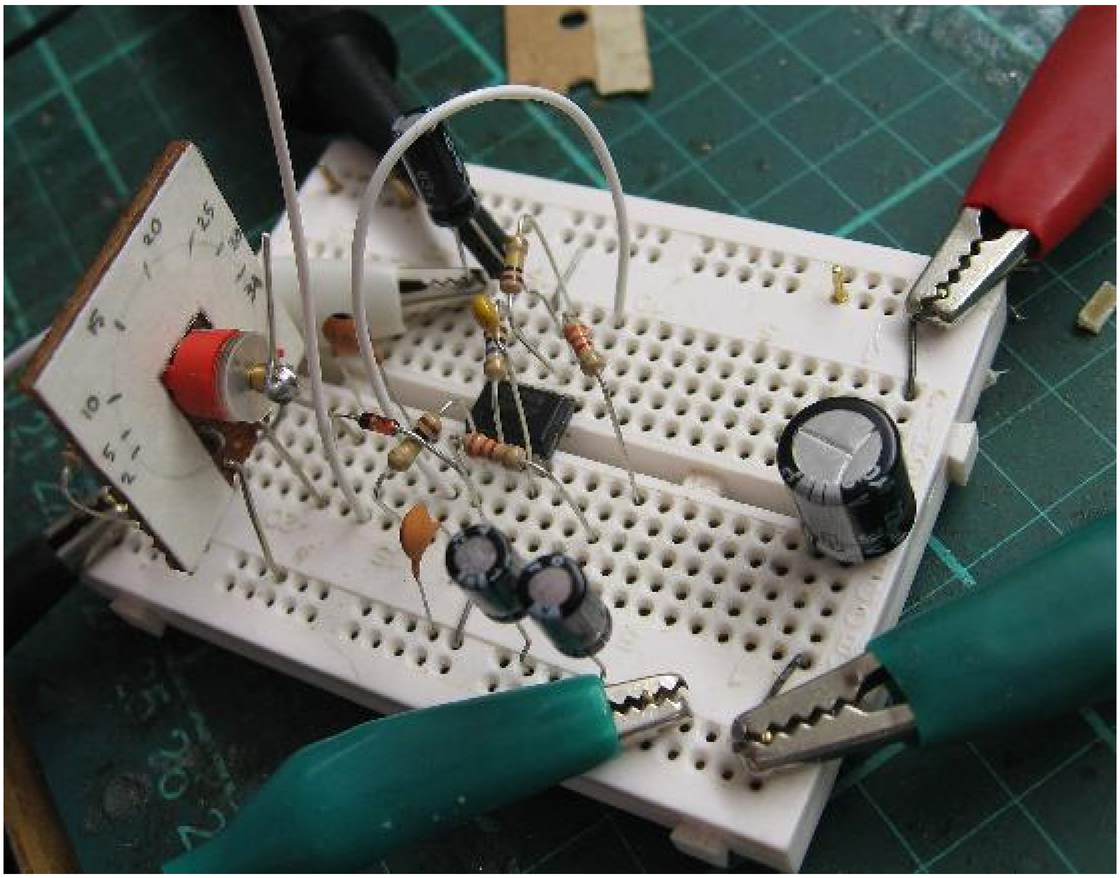
Non-Emissive Airband Receiver

2007-07-14

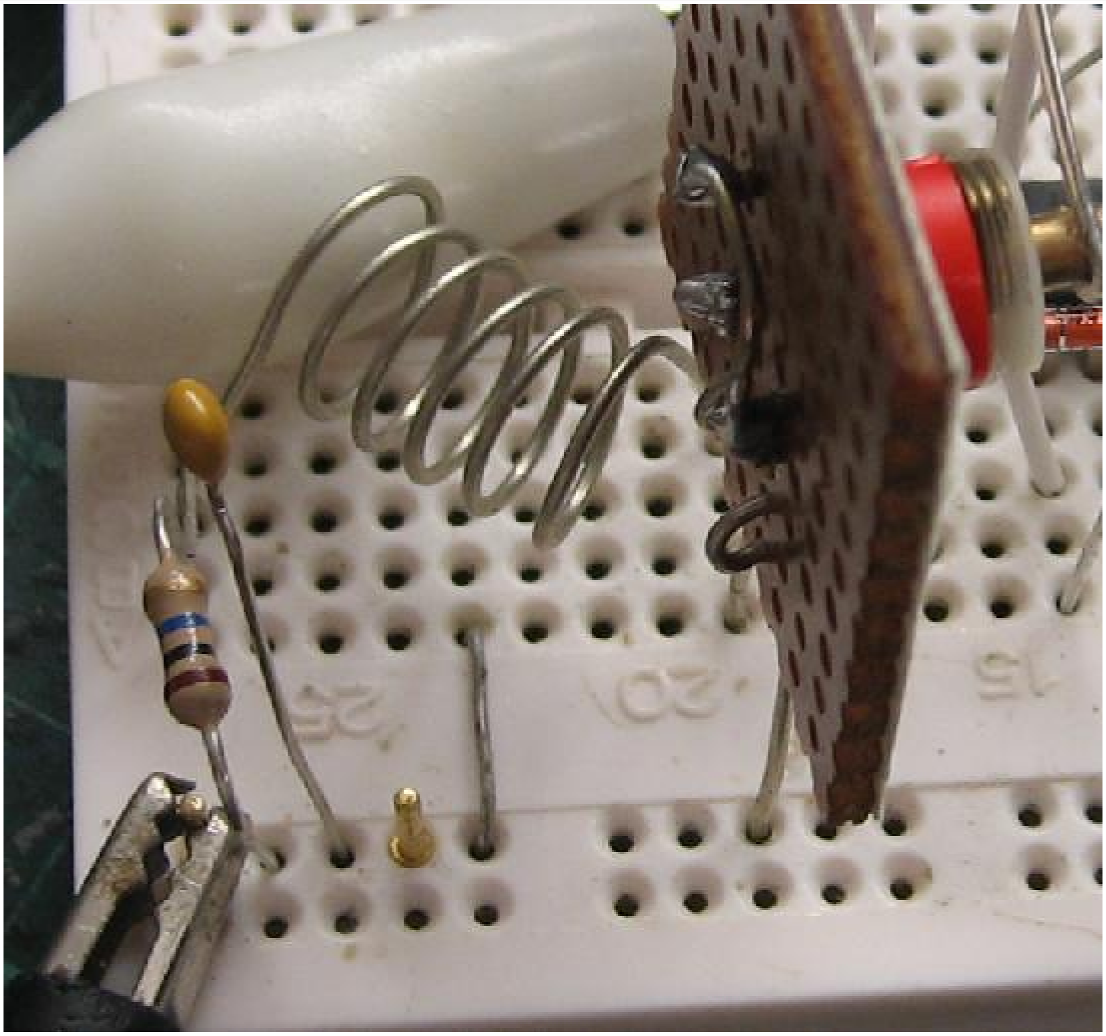
I was looking into building a non-emissive receiver for the air-band to take with me on the odd occasion I take air transport. Obviously with all the EMC paranoia with aerospace technology the only "safe" device is one with no possibility of RF emission, even at microwatt levels so regenerative and super-regenerative receivers are out.

Charles Wenzel's excellent site has an interesting circuit along these lines. Essentially an amplified VHF crystal set. It uses a biased 1N5711 to achieve good sensitivity (rather like my wavemeter), and a front-end resonator to make it sufficiently selective in the band of interest (instead of being wide-open like his Amazing All-Band Receiver).



The circuit is quite trivial, it took me only minutes to build on a solderless breadboard. I used a TL072 opamp rather than an LM358 (Which makes very little difference at all, despite having many orders of magnitude better input bias current and about three times the unity gain bandwidth. Its main advantage is its rather low noise.). Once built it works very well indeed. The selectivity is limited almost completely by the Q of the inductor in the front-end, and is acceptably wide for the application. I tried tapping down on the inductor (a few turns of tinned copper wire) to affect a better match into the detector, the improvement in selectivity isn't really worth the reduction of sensitivity.

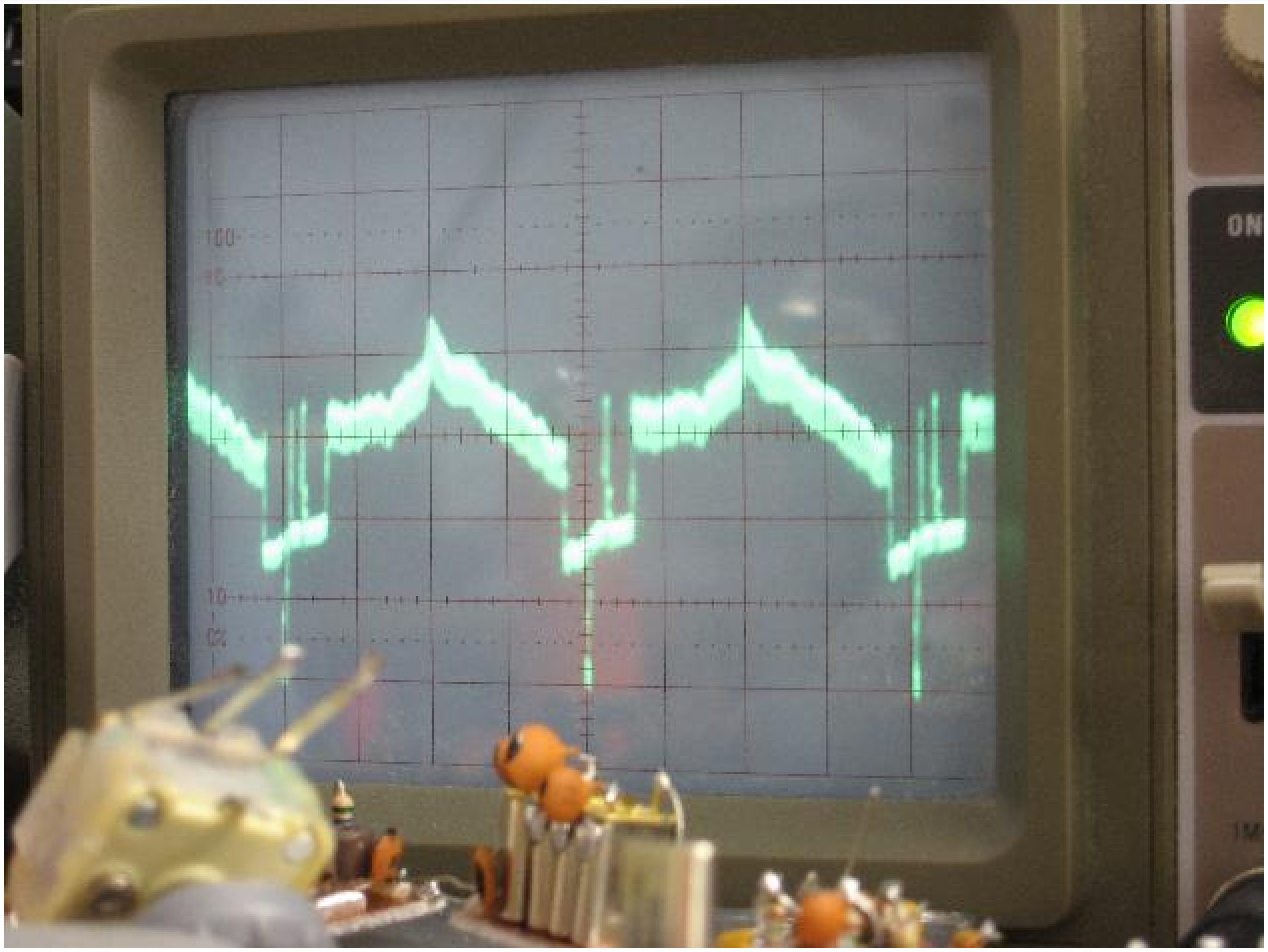
The audio gain is more than sufficient to hear the noise from the resistors in the front-end, it might be worth using less noisy devices actually. The total audio power might be a bit weak inside an aircraft, but for around town it is plenty loud.



On the FM broadcast band I could separate about three of the major high-power-end stations, specifically 2DAY, 2MMM, and 2MIX. 2WS is for some reason the easiest to tune in (at modest distortion), it may be that the circuit Q is near-ideal at 101.7 MHz, or perhaps it is just far enough away from other powerful stations that it is easier to slope-detect without confounding garbage from adjacent stations. 2DAY and 2MMM are fairly hard to separate, you have to tune below 2DAY and above 2MMM to avoid the other. 2JJJ for some reason isn't sufficiently powerful in my shack to work well with the receiver, but you can understand the speech of the announcer. 2ABC is also easily detectable, but the quality of the demodulation is not fit for its programming.

You certainly would not want to use this receiver to listen to FM broadcast, it sounds even worse than a super-regenerative receiver (and is hopelessly deaf), but perhaps with some effort in constructing a helical resonator it might be improved to the point where it was acceptable. I still think the best non-FM receiver I've built for FM broadcast is the regenerative one, which has the advantage of variable-Q and good sensitivity.

On the Airband I couldn't hear a thing with the receiver. It isn't sufficiently sensitive to hear off-air signals, but experiments were carried out with the signal generator suggests it should work fine in close proximity to an airband transmitter. It works quite well on 2 metres to hear my fredbox, and can separate it from the pagers above 2 metres. It can hear TV stations very well, especially ABN-2 and ATN-7. With a baseband amplifier of sufficient bandwidth I'd imagine it would be possible to actually watch TV (poorly) with the recovered signal!



Thoughts

Such a circuit is extremely useful around the bench. Much as Charles has built a general purpose one as a detector I am considering building one with pluggable coils to cover MF-VHF. It would not be extremely difficult to add the audio amplifier stage to my existing wave meter (currently it just has a Hi-Z headphone output).

For the original purpose of air-band reception at an airport or onboard an aircraft I think a better solution might be a TRF receiver. Well, a TRF receiver with a bandwidth of about 20 MHz! Reviewing the noise-floor math, suggests it would be quite practical to simply amplify the entire airband (after a good front-end filter) and AM detect that (maybe with an AGC loop). The thermal noise floor is around -98 dBm, which means it will need signals significantly more than 3 uV for a reasonable SNR assuming a perfect noise figure. At 20 uV the signal will need around 80 dB of power gain for a mW of audio (around 200 mV into a 32 ohm mylar speaker - quite loud). With 40 dB each of RF and AF gain this seems quite do-able with stability. Making the receiver in this manner means it requires no tuning. (i.e. you hear *everything* in band, at once). The big problem would be VHF beacons dominating the reception, but perhaps a tunable trap or two in the front-end would let you notch out any that were causing you trouble. Beacons are allocated in the 1st 10 MHz of the band, which could be rejected by the front-end BPF.

The BPF for such a receiver would need a loaded Q of only 6 at a harmonic centre of 127 MHz, so it is quite practical to build. Two resonators loosely coupled should do the trick, 100 nH and 15 pF is about right with an impedance tap about 1/3 of the way up from the cold end. 22 pF trimmers could be used to tune, or some squash/spread of the 6 turn coils (8 mm ID, 15-20 mm long). Anyway, that is back of the envelope stuff, only way to tell for sure is to build it. The RF amplifier is the most difficult part, 20 MHz wide at VHF, low noise, stable and preferably AGC-able with around 40 dB power gain.

2 comments.

2010-06-11: Non-Emissive Air-Band Receiver (Implementation & Use)
: A semi-finalised implementation of the passive air-band receiver and field testing while I was travelling in the US.

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Non-Linearity, Harmonic Generation and Frequency Mixing

2007-12-31

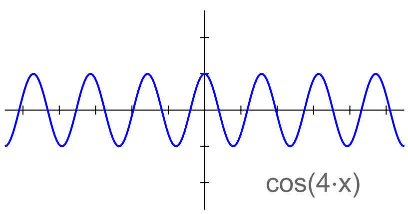
This article is inspired by SolderSmoke 72, where Bill states that he understands the multiplication identity maths, but not the actual physical mechanism of frequency mixing through non-linear circuit elements. I decided to try to answer that question, to myself mainly, to deepen my own understanding. Of course, it is also an excuse to use the new MathML support!

Multiplication vrs Addition

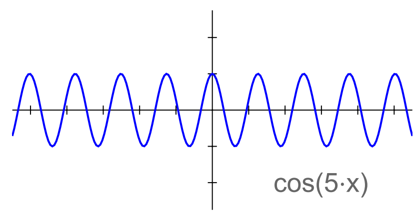
As Bill said, frequency mixing results from multiplication of two sinusoids, the familiar trig identity that most of us were forced to memorise at school shows this:

$\cos(\omega t)\cdot\cos(vt)=\cos((\omega-v)t)+\cos((\omega+v)t)2$

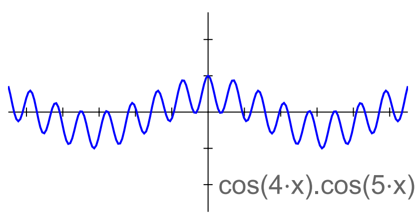
A graphical example might be:



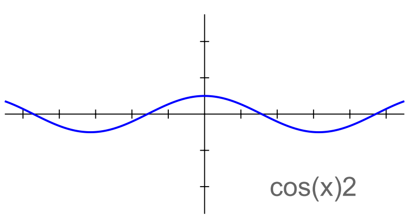
times



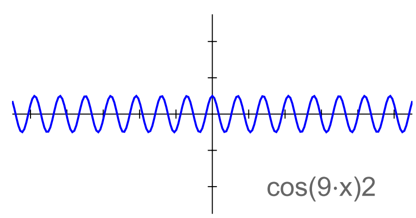
gives



which is



plus



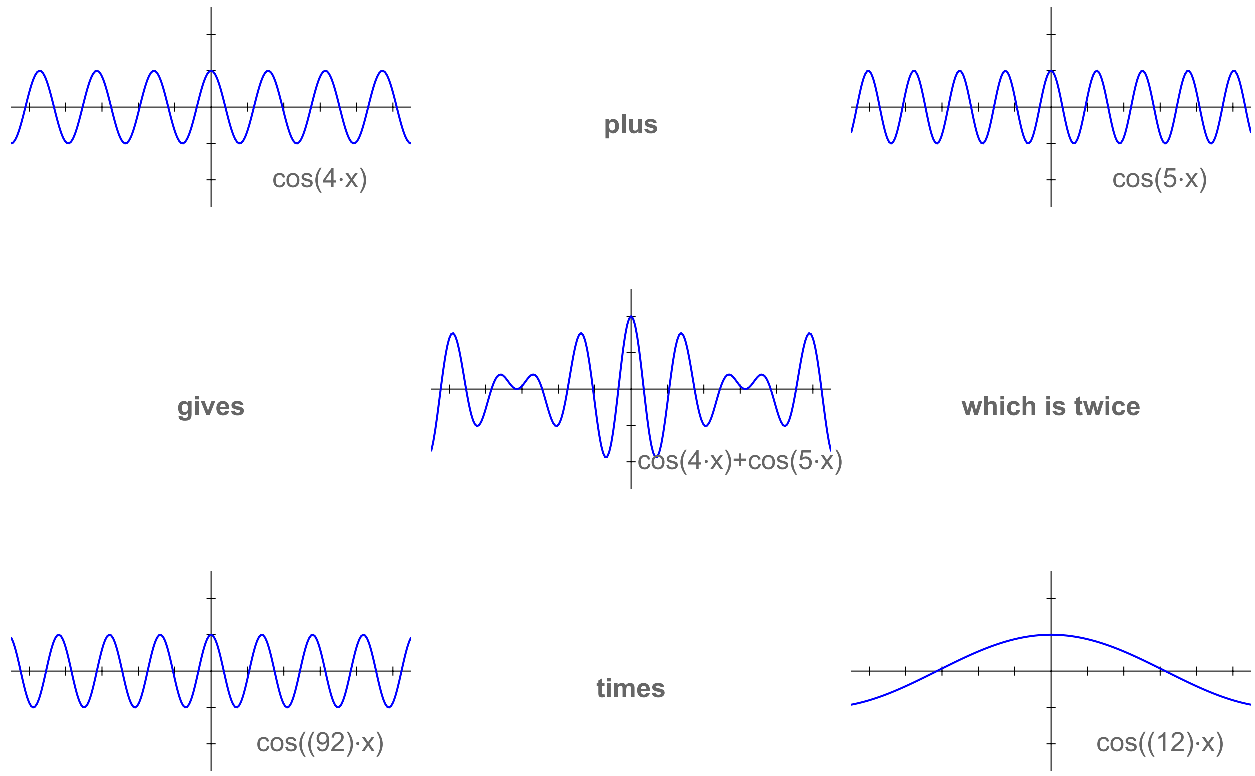
An aside to electronics for a moment: This is what we might see at the output of a perfect four-quadrant multiplier using a CRO. This might be confusing to some, compared to say the output of a DSB modulator driven with an pure AF tone (which looks like what we see below). However remember than the DSB signal is actually the superposition of two RF tones, the sum and difference frequency, with the AF and carrier suppressed. So quite rightly it looks like the beating below because it actually *is* the sum of two RF tones. For an SSB signal you'd see just the one constant RF tone as one product is suppressed/filtered. For a two-tone test you'd see the beating again, and a more complex 4-tone superposition for a two-tone DSB signal.

Simple addition (superposition) on the other hand, produces the characteristic "beating" pattern, but this is **not** frequency mixing. The components are simply superimposed. For perfectly linear systems no mixing products

 XHTML | CSS | CSS toggle

$\cos(\omega t)+\cos(vt)=2\cos((\omega+v2)t)\cos((\omega-v2)t)$

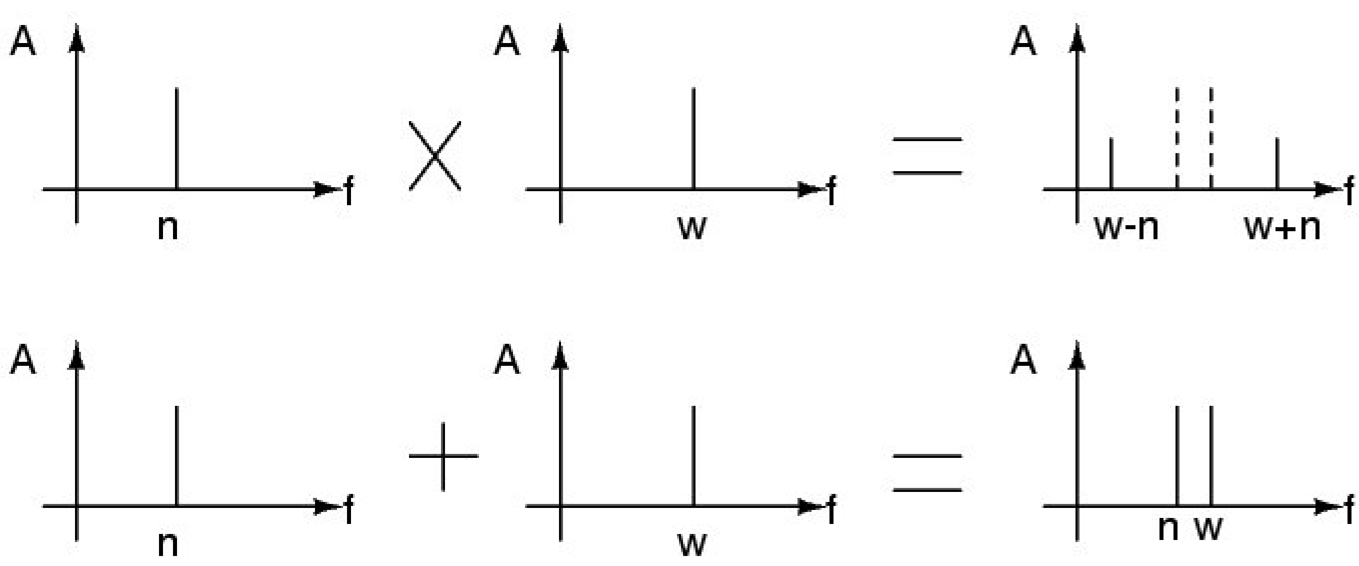
A graphical example:



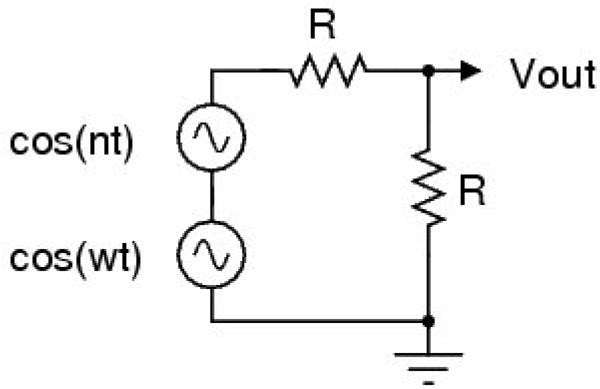
The envelope of the ω-v2 component is clearly visible, but a filter can't extract energy at ω-v2 because there is *none* there, neither is there energy at ω+v2. Filters at ω or v would however recover the individual components. This is obvious if we use our first multiplicative identity upon each apparent "component", essentially reversing the process and giving us the separate ω and v tones back again. You might like to think of the sum of two tones as that which would result from the multiplication of tones of 2 amplitude at their average and half their difference. This is somewhat intuitive if you think of it as the result of DSB modulating 2cos((ω+v2)t) with 2cos((ω-v2)t) which is cos(ωt)+cos(vt).

In the Frequency Domain

I personally find it somewhat confusing to visualise this in the time domain, so here is a frequency domain picture of what is going on:



Lets first consider a linear circuit; two resistors R fed from two AC voltage sources operating at ω and v radians per second, delivering 1 volt pk-pk each.

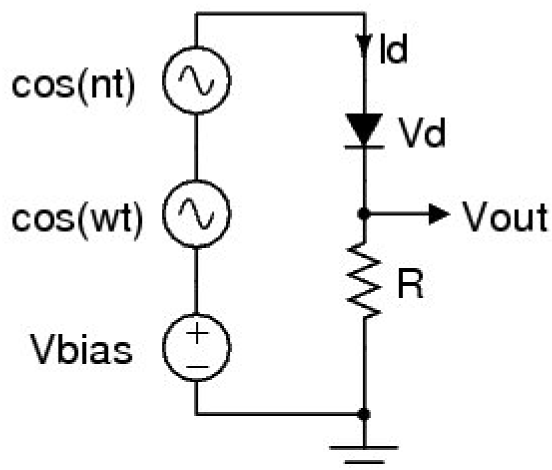


The transfer function is perfectly linear, the output voltage is one half the input voltage, and the input voltage is the simple sum of the instantaneous voltages of each AC source.

Vout=12(cos(ωt)+cos(vt))

From our identity investigation above, this contains only ω and v components in the frequency domain. No mixing products are produced.

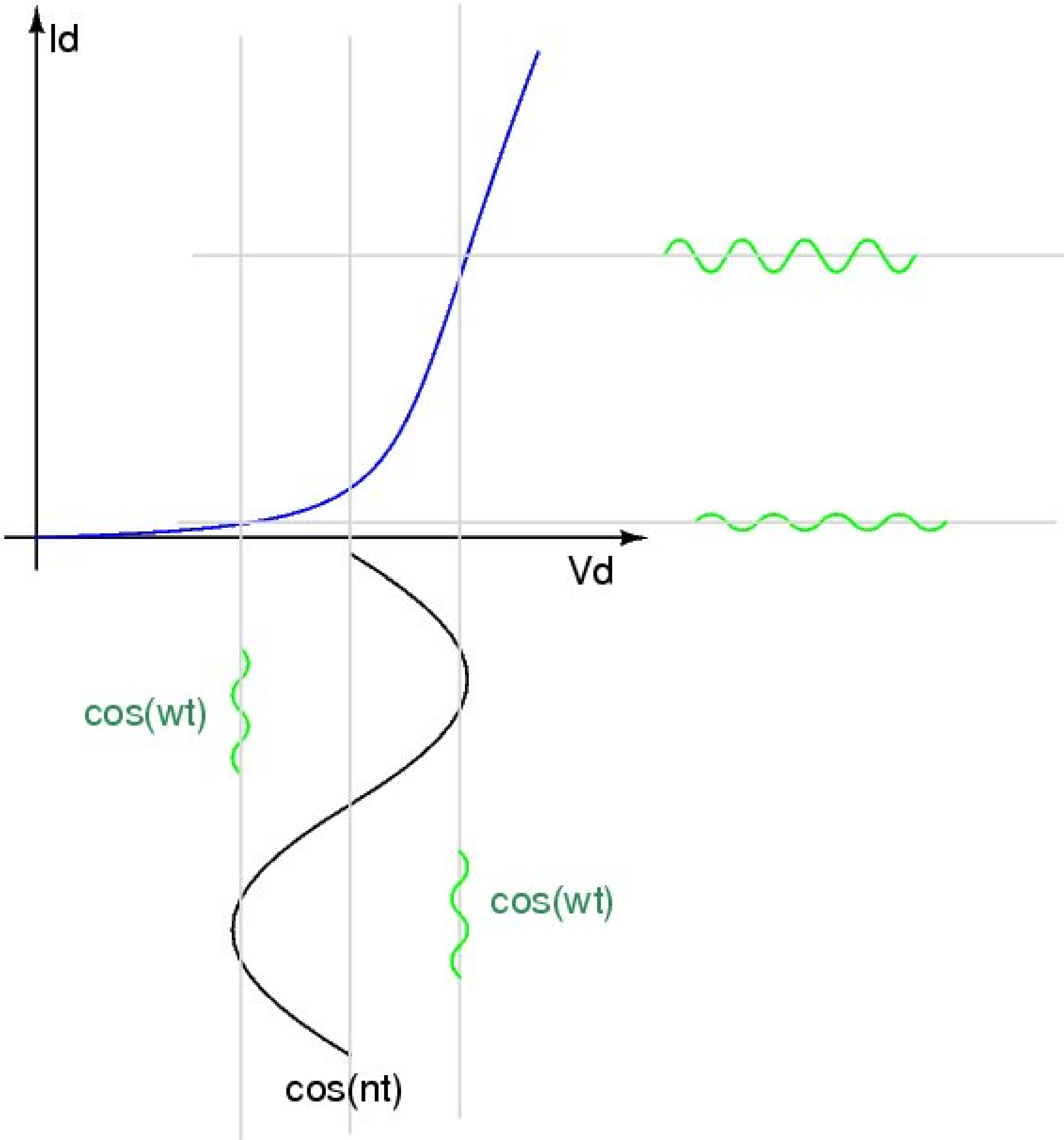
Now lets replace the series resistor with a diode.



The diode is the classic non-linear component, its dynamic properties described by the Shockley diode equation:

Id=Is(eVdnVT-1)

Unfortunately this is absolutely horrible to solve analytically, and I won't attempt to do so here. Read the wikipedia Diode Modelling article for a starting point on the gory details. Instead, I'll just assume the diode gives as an exponentially changing "resistance" with the applied voltage. This is sufficient for a hand-waving argument to show how multiplication occurs.



Consider cos(ωt)+cos(vt) being exponentiated by the diode Vd/Id characteristic. Assume v is much smaller than ω, such that we can consider cos(vt) to be almost DC during cycles of cos(ωt). We'll also assume there is a DC bias that prevents the diode rectifying the signals and they are of sufficiently small amplitude to be operating near the "knee" of the diode curve - this simplifies the argument and helps the visualisation, but isn't strictly required. The voltage seen across the resistor varies something like eAcos(ωt)+k. Where k is current value of cos(vt) and A some small amplitude constant. You can visualise this as cos(vt) slowly sliding the cos(ωt) up and down the diode Vd/Id curve. Towards the bottom Id varies quite slowly with Vd, so Vout is some small almost constant factor of (a distorted) cos(ωt), further up this "constant" increases as the slope of the Vd/Id curve increases and so the amplitude of the passed cos(ωt) increases. You can think of it as cos(vt) modulating the diode's dynamic resistance and hence multiplying its instantaneous value with cos(ωt).

Actually both voltages affect each other, and the products produced also mix. This is intermodulation distortion.

All this non-linearity also causes harmonic distortion of singly applied signals, distorting their waveshape and pushing some of their energy into harmonics. In the simple diode example all kinds of junk is produced, with them all intermodulating each other right down into the noise floor.

More Rigor

I am always troubled by hand-waving arguments, even if they provide some intuitive understanding. Quite frequently such "lies to children" are just that, complete falsehoods of dubious pedagogical merit. Here is a more mathematically sound argument...

Consider the Taylor expansion of ex:

$e^x=\sum_{n=0}^{\infty}\left(\frac{x^n}{n!}\right)$

It is therefore easy to show that e^x-1 is well approximated by $x+\frac{x^2}{2}$ for small x. Remembering for the diode equation our x here will contain V_d and that $(a+b)^2=a^2+2ab+b^2$ it is easy to see that there will be an $a\cdot b$ term in the transfer function somewhere. When a and b are our sinusoids $x=a+b$ and we have our multiplying action!

This is the very heart of intermodulation through a diode.

The other higher-order terms are less important because their denominator grows as n! and will soon be into the noise floor, but it is helpful to remember they exist. In RF systems the 3rd-order products are of some concern, because they are quite close to the signals of interest. 3rd-order intercept is hence a figure of merit for high-performance mixers.

This same expansion explains harmonic distortion if you consider that $\cos^2(\omega t)=\frac{1+\cos(2\omega t)}{2}$ and that $\cos^n(\omega t)$ has a $\cos(n\omega t)$ term in general.

It is possible to show that all non-linear systems will produce harmonics and intermodulation products. The phase and amplitude of the products themselves are a function of the particular system, only in perfectly linear systems do the higher-order terms vanish.

Multiplication by Switching

Switching mixers can be thought of as multiplying the signal by +k or -k on each excursion of the local oscillator waveform. Selectively inverting the signal at the LO rate. Basically the LO is a square wave and its harmonic comb is convolved with the input signal, resulting in a heap of mixing products around each harmonic as well as the fundamental. Filtering is usually used to pick the IF desired, but this also gives an idea how harmonic and sub-harmonic mixing works.

Symmetric ±k multiplication is not strictly required, even just chopping the signal on and off at the LO rate is sufficient to achieve frequency mixing (but suffers from other problems due to lack of balance). This can be visualised as sampling the signal at the LO rate, where the IF is an alias. If you remove the V_{bias} from our diode example above you have an unbalanced product detector which functions essentially by switching (the alias being at baseband). In practice it would need to be driven fairly hard by the LO and would tend to suffer from AM break-through, however such circuits are used after IF filtering in many receivers as the signals presented to it are well controlled.

Although not normally described as mixing, the rectification often used to demodulate full-carrier AM is also an example of mixing by switching. The carrier toggles the rectified path on and off at the carrier rate, mixing itself with the sidebands also present and generating the baseband image (basically folding both sidebands over each other).

True four-quadrant multipliers are ideal mixers and the LO signal remains as pure as it was injected. "Gilbert Cell" mixers approach this, and also suppress the injected LO and RF signals because of their symmetry. Leaving mostly the IF (and the image) at the output, simplifying the filtering of the IF.

Parametric Mixing

We've only discussed time-varying resistance causing intermodulation here, but it is possible to vary reactance as well (and impedance in general). Parametric mixers use their pump waveform (LO) to alter the reactance of tuned circuits at the LO rate. One or more tuned circuits may be used, depending on the desired result.

In a parametric mixer one tuned circuit is set up to resonate at the desired IF, and other at the signal frequency, they are coupled through a varactor which is then pumped at the sum or difference, converting energy at the signal rate into that of the IF rate. The actual mechanism can be considered energy shunting between the coupled resonators as their LCR properties are varied, but the mathematics is pretty ugly. Double-sideband parametric mixers have three resonators, allowing extraction of both the sum and difference IFs. The IF resonators are generally called the idler, which I assume is a term from their mechanical origin?

It is possible to use a parametric mixer as an amplifier. Parametric mixers have gain as the pump energy is converted into the signal and IF frequencies. Hence a small signal in the signal resonator experiences amplification and can be extracted there if so desired (directional couplers/circulators are useful to isolate the input and output). The gain of the amplifier is controlled by varying the amplitude of the pump. Pump too hard and you simply have a parametric oscillator at the IF and signal frequencies.

Degenerate parametric amplifiers have only a single resonator (i.e. their IF equals the signal frequency) and are pumped at exactly twice their resonance frequency. This makes them quite phase-sensitive as the pumping must be coherent. The pump frequency for any parametric device must be at least twice the signal frequency.

Parametric mixing and amplification is typically used at very high frequencies, usually microwaves up to light. It is an extremely common practice in optics and low noise microwave converters. However, it can in principle be used at any frequency, and even in non-electronic systems, such as mechanics. The playground swing is a

familiar example to all of us, changing your centre of mass dynamically alters the inertial terms of the system and pumps the oscillation (degenerate parametric amplification).

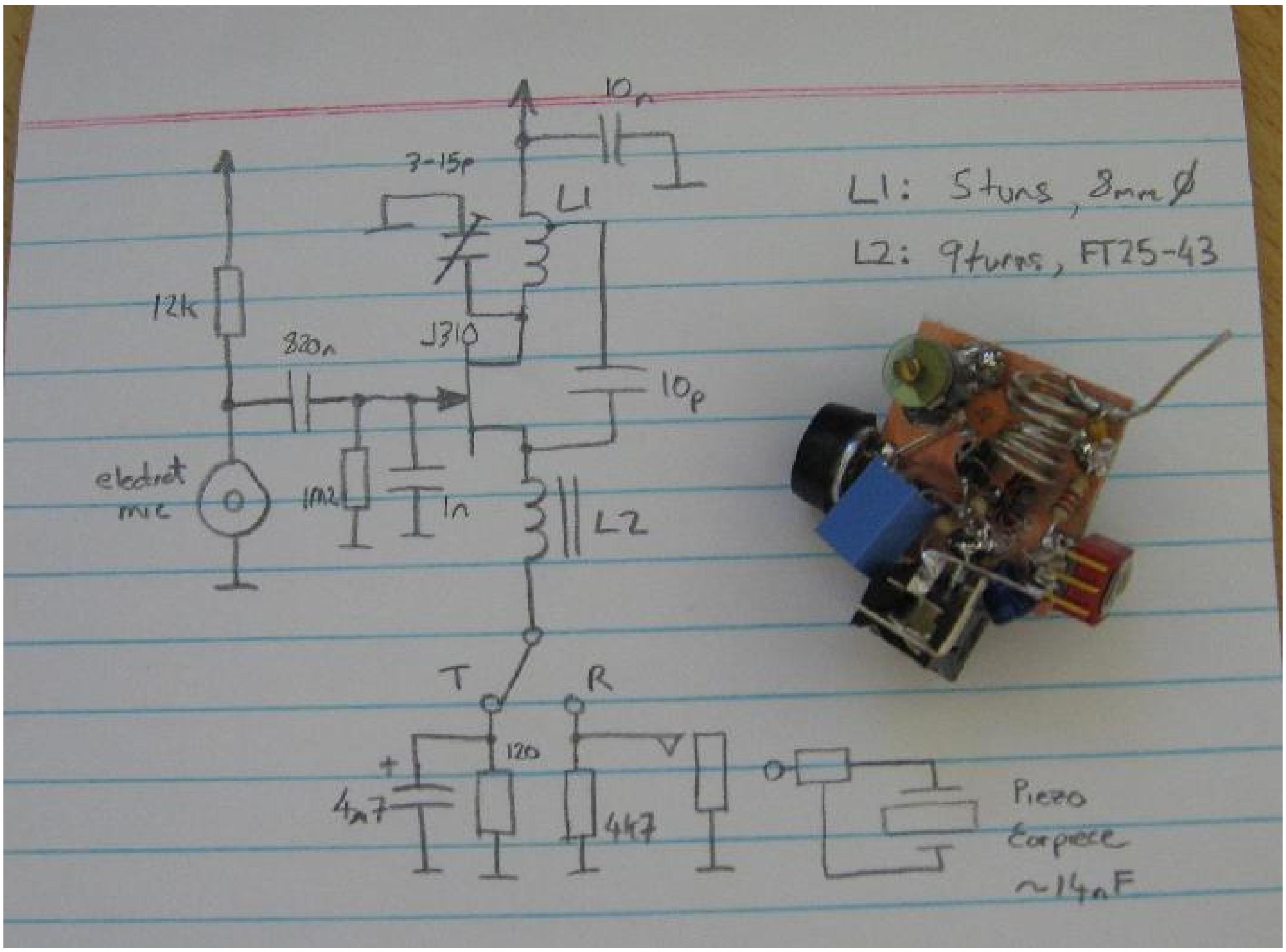
1 comment.

Attachments

title	type	size
Linear System Diagram Source	application/postscript	9.722 kbytes
Non-Linear System Diagram Source	application/postscript	10.569 kbytes
"Non-Linear Multiplication" Diagram Source	application/postscript	9.788 kbytes
The Frequency Domain Picture Source	application/postscript	10.181 kbytes

One Transistor Voice Transceiver

2008-03-01



The Inspiration

Michael Rainey's recent adventures with minimalist transmitters and receivers has been an active topic of discussion on QRP-L. Michael's One Transistor Direct Conversion RX inspired me to finally attempt a project I've been toying with for years; a one transistor voice transceiver. John Kirk VK4TJ also exchanged some emails with me about single transistor TRXs, in particular John reminded me about the QSK-1, Bob Culter N7FKI's single-2N7000 based CW transceiver.

A one transistor CW TRX isn't that difficult to achieve, but I wanted a phone rig. I was under no illusion that this would be extremely difficult to achieve, openly doubting if it was even possible. I agreed to be happy if I managed to achieve any kind of "toy" walkie-talkie style performance.

The General Concept

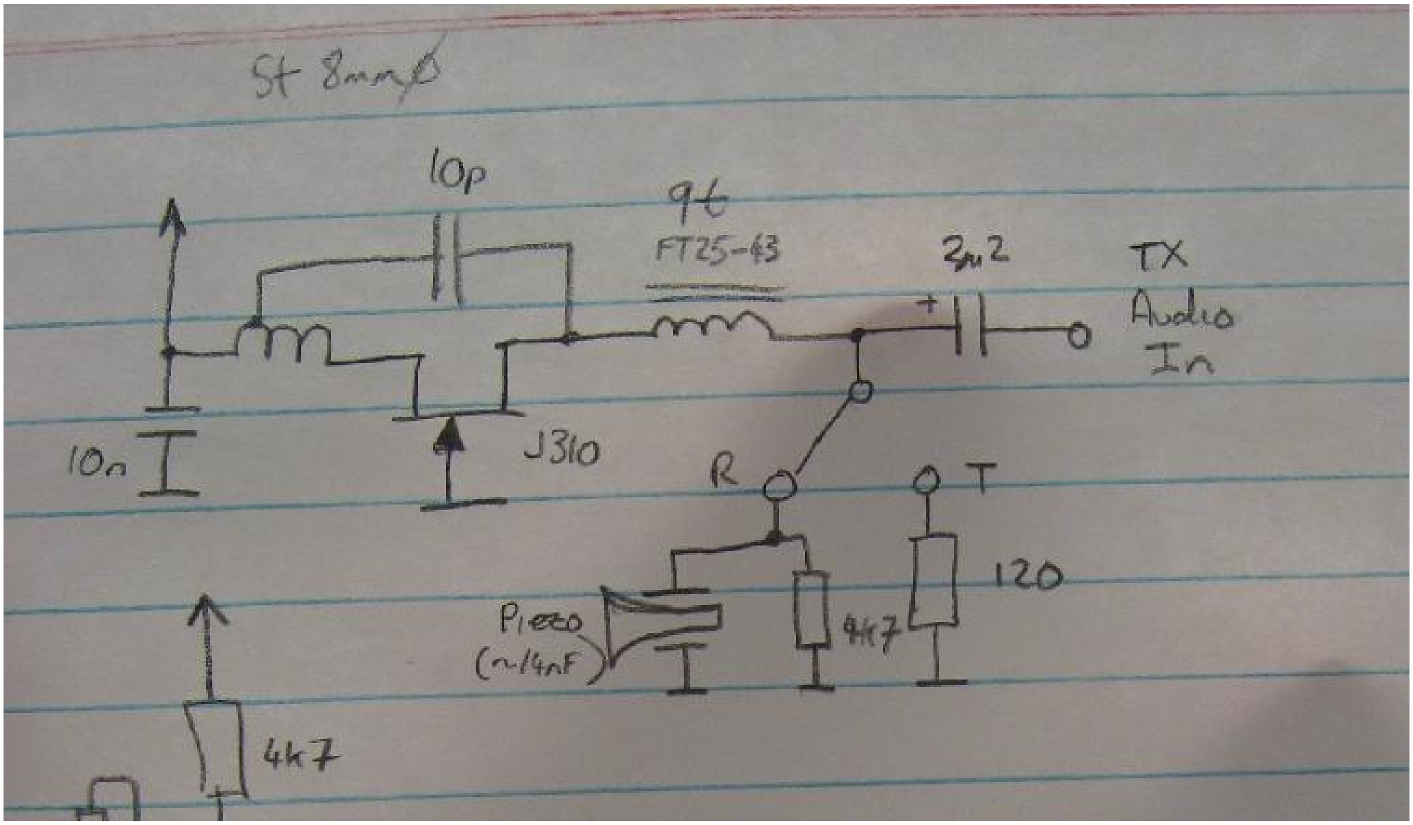
I decided to go with minimalist WBFM transmitter and a super-regenerative detector. The topology of both circuits is extremely similar, and I had previously got a single transistor FM broadcast receiver working fairly well. It is pretty easy to turn a self-quenched super-regenerative detector into an oscillator by just altering source/emitter circuit to prevent quenching. This is the approach I took.

I picked the FM broadcast band as a candidate frequency band. It is not excessively high of a frequency, WBFM is already common there, and locally there is an empty gap around 100 MHz where Low Interference Potential Devices are allowed to operate (wireless microphones, toys, etc). My spectrum analyser also works well on 3 metres, and includes WBFM demodulation. There is no reason in principle why the resulting device could not be rebuilt for 10 metres, which is very sparsely populated, or even maybe 70 cm. 2 metres is too busy now days for a free-running LC oscillator to be

frequency stability would become a big problem. Antennas for HTs are much easier at UHF than HF, which might be considered an advantage of using 70 cm.

A Starting Point

I started with a grounded-gate JFET oscillator. (Using a JFET simplifies the biasing components, while I wasn't trying to build a minimum-component receiver, simplicity is always preferable.) A SPDT switch in the source provided the switching between straight oscillation and quenched super-regeneration. For RX, a crystal ear piece was used as both the audio output device and the quenching capacitance (about 14 nF). The resistor paralleling (4k7) it was chosen to give a quench of about 25 kHz which corresponded to the best sensitivity. (Slightly more AF output was available when the quench was dropped to around 18 kHz, but the passive filtering required to remove the quench tone killed any extra AF output, so I kept the quench supersonic.) For TX just a single resistor was switched in resulting in CW oscillation. A trimmer (not show below) in the drain circuit provided tuning from about 70-180 MHz.



At this point, the RX was working fine. The audio output level is quite low, requiring a quiet room, but the receiver is quite sensitive, picking up even the weaker FM broadcast stations with no antenna at all. (The 8 component RX is in itself quite impressive in its minimalism!)

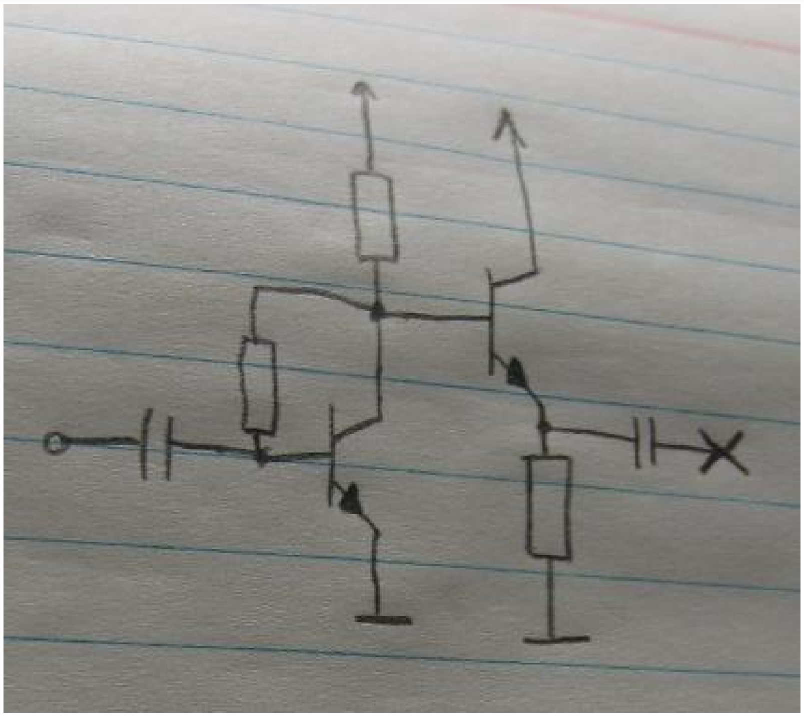
Coupling to the source for an antenna proved to be practical for both TX and RX but did cause some frequency instability with hand capacitance. Coupling to the cold-side of the tank offered no better stability. The antenna was left off for further experiments, it was just getting in the way, and was something that could be left out for now.

The frequency shift between TX and RX turned out to be only about 50 kHz for my ugly birds-nest of a prototype. This was completely unexpected. Previous experiments had delivered circuits with more than 800 kHz of shift between CW and quenched oscillation. The 50 kHz shift is pretty acceptable with WBFM, considering the selectivity of the RX.

Getting TX Modulation

To FM modulate the TX carrier I injected 100 mV of audio from my signal generator into the junction between the source resistor and the RFC. This resulted in an acceptable deviation, similar in "loudness" to commercial FM stations. However, here I had a problem. 100 mV of audio into a low impedance point would require some kind of audio amplifier, no passive microphone could deliver this.

For the purposes of further experimentation I built a two transistor AF amplifier which could amplify a dynamic or electret mic signal up to the required level and drive the low impedance of the source. Note that this particular circuit is capable of providing RX audio amplification as well, and can drive 32 Ohm headphones to a reasonable volume.



In an attempt to avoid the need for the AF amplifier I lifted the J310's gate lead and took it back to ground with a 1M resistor, paralleled with 1 nF of RF bypassing. This gave me a higher impedance point into which I could inject much smaller AF signals and get the JFET to amplify the signal itself. The result was fairly good deviation with just a dynamic Mic and a DC blocking capacitor connected to the gate - at least as long as you yell into the microphone!

A down side was this change to the circuit caused the RX/TX frequency shift to increase to almost 500 kHz. I had always planned to include a switched trimmer to correct the RX/TX shift, so while annoying, this wasn't a fatal flaw. The RX frequency was higher, so a DPDT switch could be used to switch in extra capacitance on RX. This gives you a RIT feature too which is very helpful in minimising RX audio distortion.

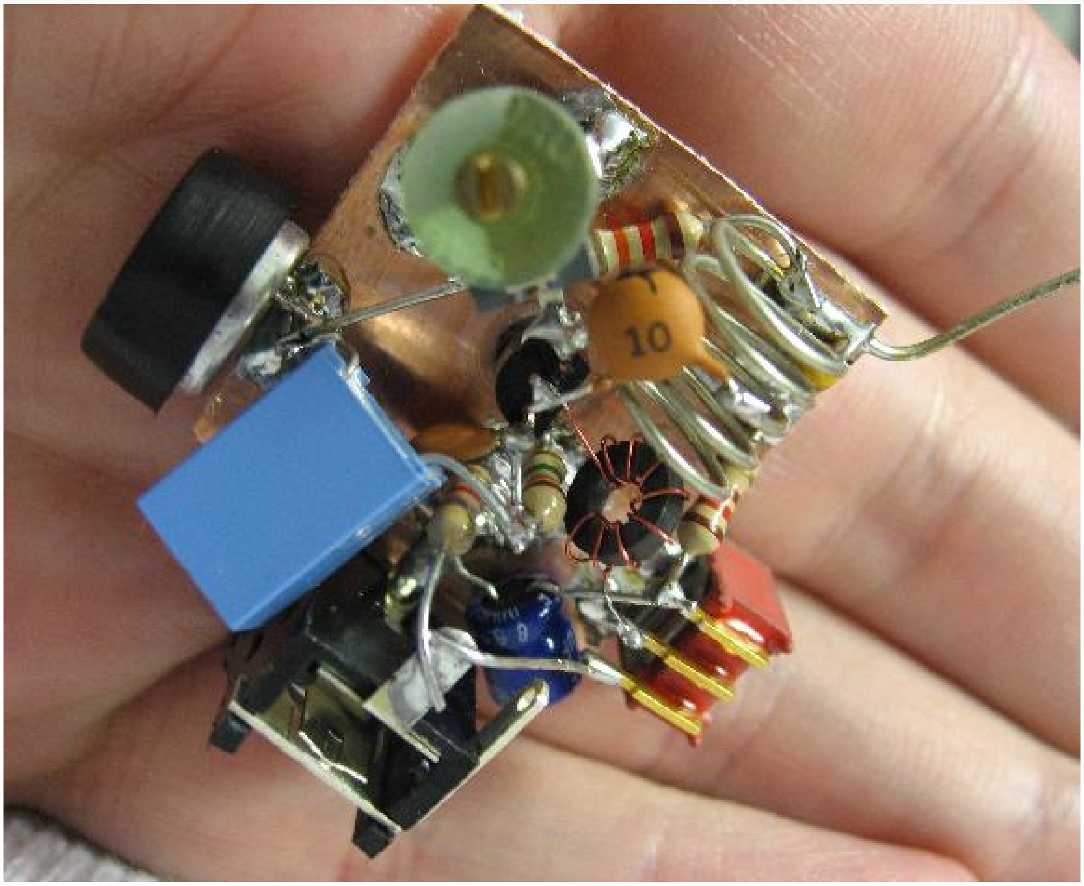
The low deviation was a problem though, it was no where near as good as with the source injection with the AF amplifier, and combined with the fairly poor AF output of the RX this configuration is just barely usable (unit-to-unit anyway)...

After much fiddling around I decided to cheat and use a electret microphone instead of a dynamic one. A electret mic has an internal FET and can't be classified as "passive" (but more importantly for the circuit, its output is significantly greater). Along with adding a AF bypass capacitor at the source resistor, this provided acceptable deviation with no additional stage of AF gain and only a moderately raised voice.

A carbon microphone might be a way to avoid the extra "active" device. I also contemplated directly pulling the tank frequency with either the capacitance of a microphone diaphragm in close proximity, or a piece of ferrite glued on to a diaphragm which might be rubber or acetate sheet stretched across a PETE plastic bottle top as an acoustic "horn". The mechanics of this were thought too fiddly for the proof of concept unit, the purists might like to explore this route however.

Success

So at this point, I have a working toy VHF transceiver using only a single J310 transistor and just a handful of other components. The miniature switch and earphone socket dwarf most of the other components, and the current drain is next to nothing.



I've contemplated building a pair of these circuits into Eclipse mint tins.

I do really need to build at least two, so I can have a proper QSO unit-to-unit.

Improvements

The proof-of-concept circuit has a lot of limitations, the biggest is no RIT or fixed TX/RX frequency shift compensation. When I tightened-up the initial messy layout, the circuit actually ended up having a much smaller T/R frequency offset. Almost acceptable considering the selectivity of the RX, but wrong enough to limit its performance significantly.

At its most primitive using a DPDT T/R switch and a small compensating trimmer would allow correcting this. I am tempted however to use varicap tuning for the RIT. Some TX shift would be handy for "netting" three or more units, so perhaps a pair of pots; tune + RIT.

The microphone isn't cut off on RX, you can hear it in the RX audio. Removing the microphone supply or shorting out the transistor gate would fix this. More T/R switch poles or some diode switching associated with the RIT implementation sounds the most feasible.

The TX frequency takes a moment to settle while the AF bypass capacitor on the source charges. This isn't a big deal, but you can watch the oscillator sweep up the band on the SA as it charges when you first key the transmitter. Reducing the value of the capacitor helps, but reduces the low-frequency deviation. Some adjustment of TX frequency is available by varying the source resistor, but this also changes the output power and can only be done within certain limits (before it starts super-regenerating at a fraction of a Hertz or the transistor saturates). It is possible to tune out the T/R frequency difference by this method.

Obviously coupling the tank to an antenna needs to happen in the final unit too.

More Devices?

There is a obvious trade-off here in performance vrs device count. For one active device you get a quiet RX with moderate TX deviation, and an output power in the milliwatt region: Usable, but only really to say you've done it!

Adding another transistor gives you either better RX AF gain, or more TX deviation. Two extra transistors lets you have quite good TX and RX performance, but you are still tied to the earphone for RX. Extra switching lets you drive a small speaker which will also act as the microphone, but a 4PDT TR switch is required and circuit complexity is rising fast. An dual Op-Amp IC gives you similar options for more current draw.

If you don't mind extra transistors you can just build yourself separate Microphone and Speaker amplifiers. Three or four extra transistors gives you a quite capable little rig. You can even just build the TX and RX separately and switch the power and antenna, at that point though, you have a transceiver not unlike the Fredbox.

The AM signal of the Fredbox is more compatible with the super-regenerative detector too, in the sense that tuning is not

FM in the current circuit, but a modulated buffer would be a better idea to minimise FM. Crystal locking the TX frequency would be an option for an AM rig.

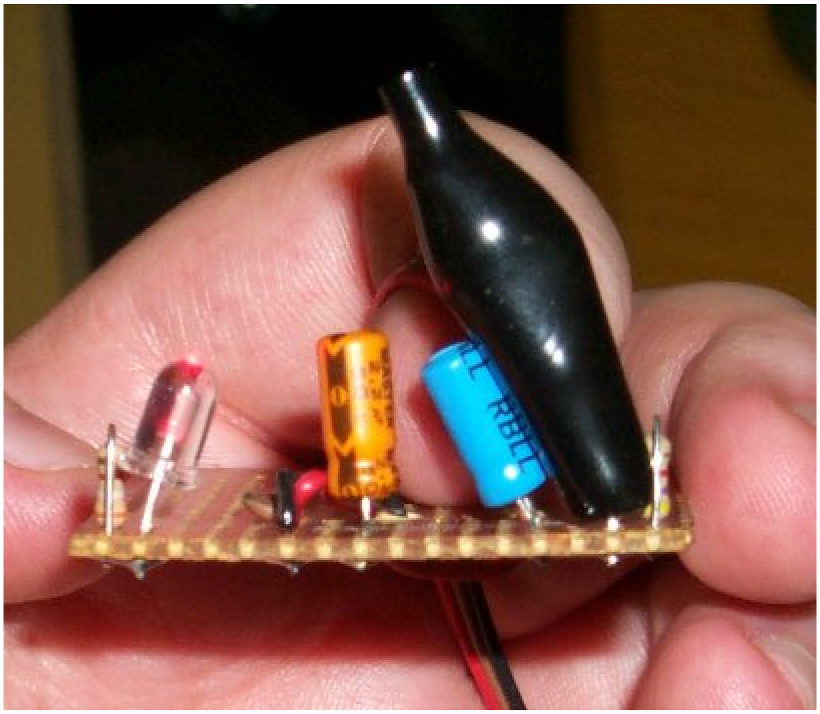
RF buffering on RX would reduce LO radiation. On TX you could develop more power with a stage or two of amplification and both would help prevent the antenna loading pulling the frequency around while in use.

So even if limited to say, 6 transistors total you could make a pretty good transceiver with a tiny footprint and power consumption. Of course, it would have none of the wow factor of using a transceiver with only one transistor!

8 comments.

Optical Tachometer

2002-12-14

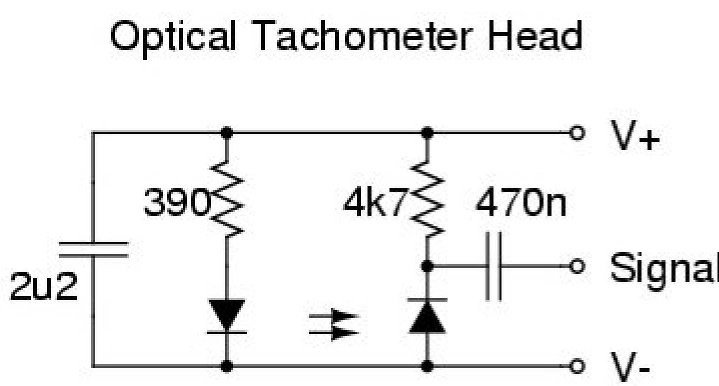


I built this simple reflection-pair optical tachometer head for my CD-ROM structural strength experiments. I needed a simple and accurate way of measuring their angular speed, while I spun them, before I could proceed to more scientific tests.

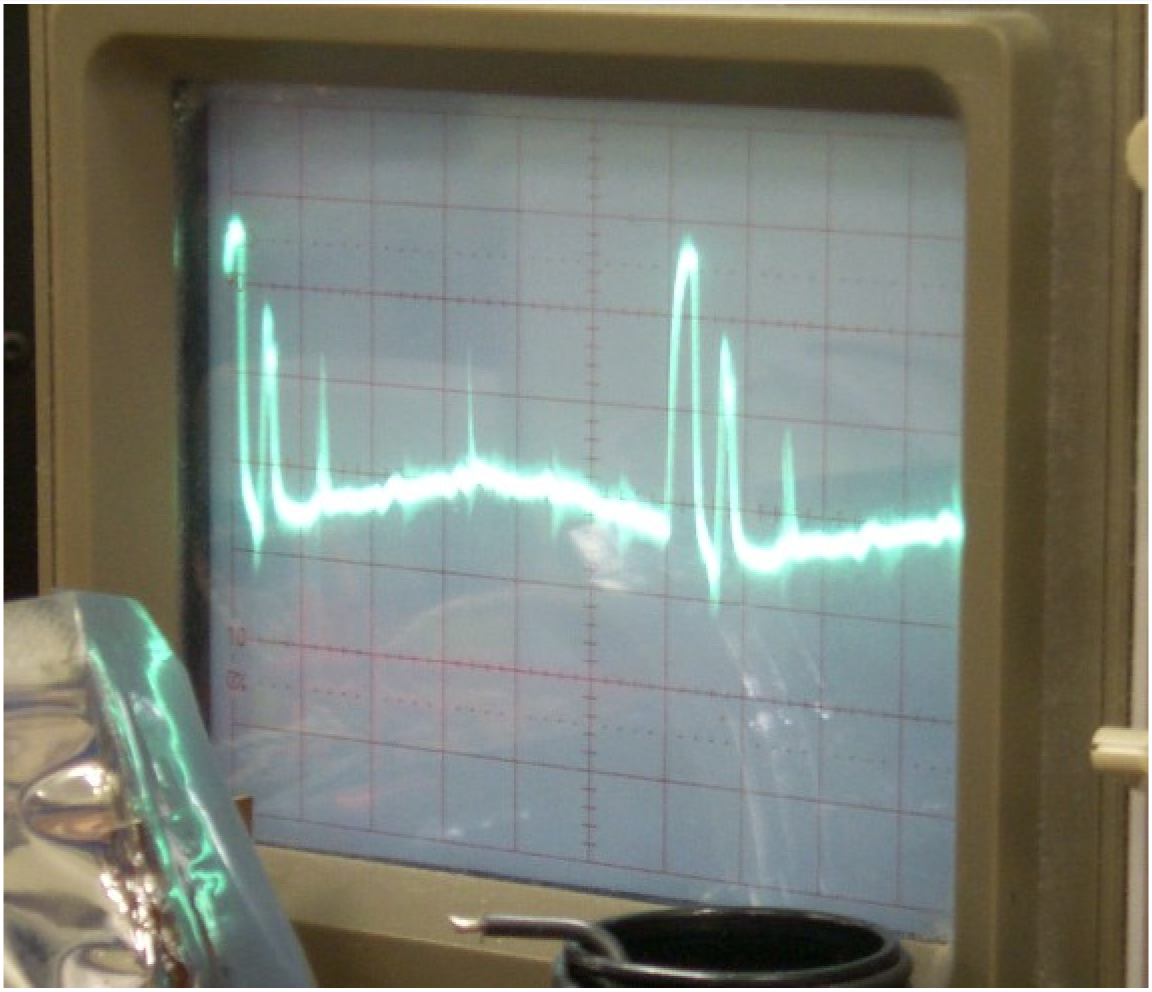
The circuit is simplicity itself. There is a red LED to illuminate the target and a photo diode in photo-conductive mode to pick up the reflected light. A simple three-wire (supply/signal/common) umbilical feeds back to the power supply and readout. Currently I use my CRO for the readout, but I have left room on the head board for a pre-amp to help integration with a counter circuit at a later stage.

As you can see in the picture, I am using a boot from a alligator clip as the light shield. The resulting signal is about 50mV pk-pk for the difference between the shiny CD surface and a black region painted on with a whiteboard marker.

The supply voltage is 6V, but anything that correctly biases the red LED and photo diode with the given resistor values will work fine. I used 4 AA penlight cells in a holder than offers a 9V battery snap style connector.



Below is an image of the signal observed while monitoring a CD being spun via a small electric motor. The two peaks are from the non-reflective black lines on the CD the smaller blurry peaks are the RF noise from the electric motor (Their constant phase relationship with the optical signal indicates the drive connection is solid with no slip, their number also confirms the motor has 3 poles). The vertical gain is 20mV/div and the horizontal rate 2ms/div, giving an RPM of about 4800.



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Attachments

title	type	size
circuit postscript source	application/postscript	9.903 kbytes

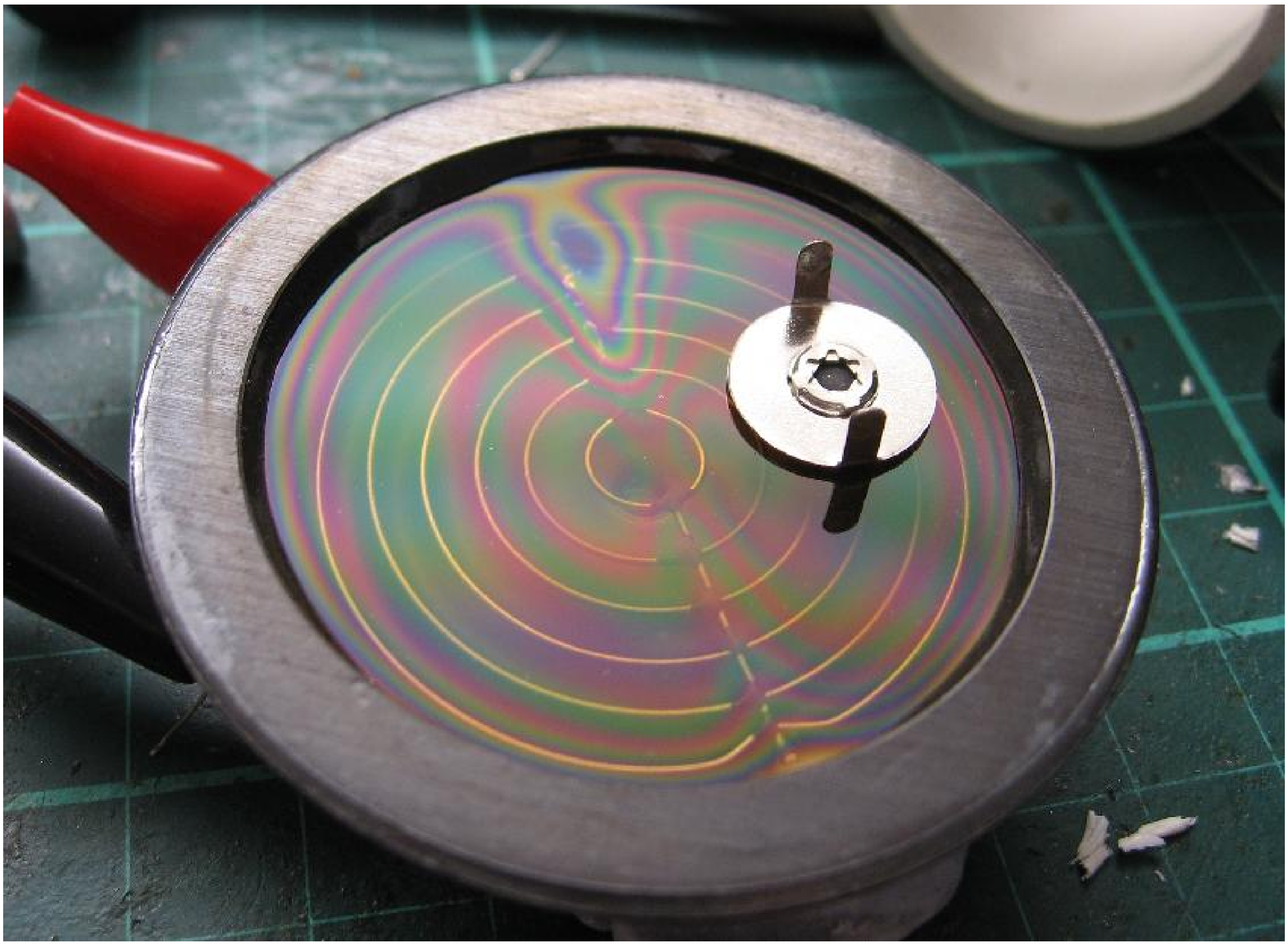
 XHTML | CSS | CSS toggle

Pancake Geiger Müller Tubes and a new Power Supply

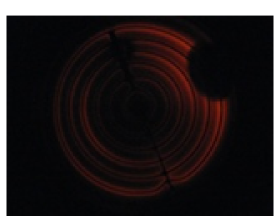
2009-06-07

I found some very nice ~ 50 mm pancake Geiger Müller tubes on eBay. They were about $60 AUD landed from the Ukraine, so naturally I couldn't help myself, I bought a pair.

They are fairly modern devices, built in the 90s with a Neon/Bromine fill and an operating voltage of about 400-500 volts. Their end-window is a bit thicker and more alpha absorbing than the one in my old high school tube (likely for the required mechanical robustness to not implode), but their overall sensitivity is much better because they are physically larger.



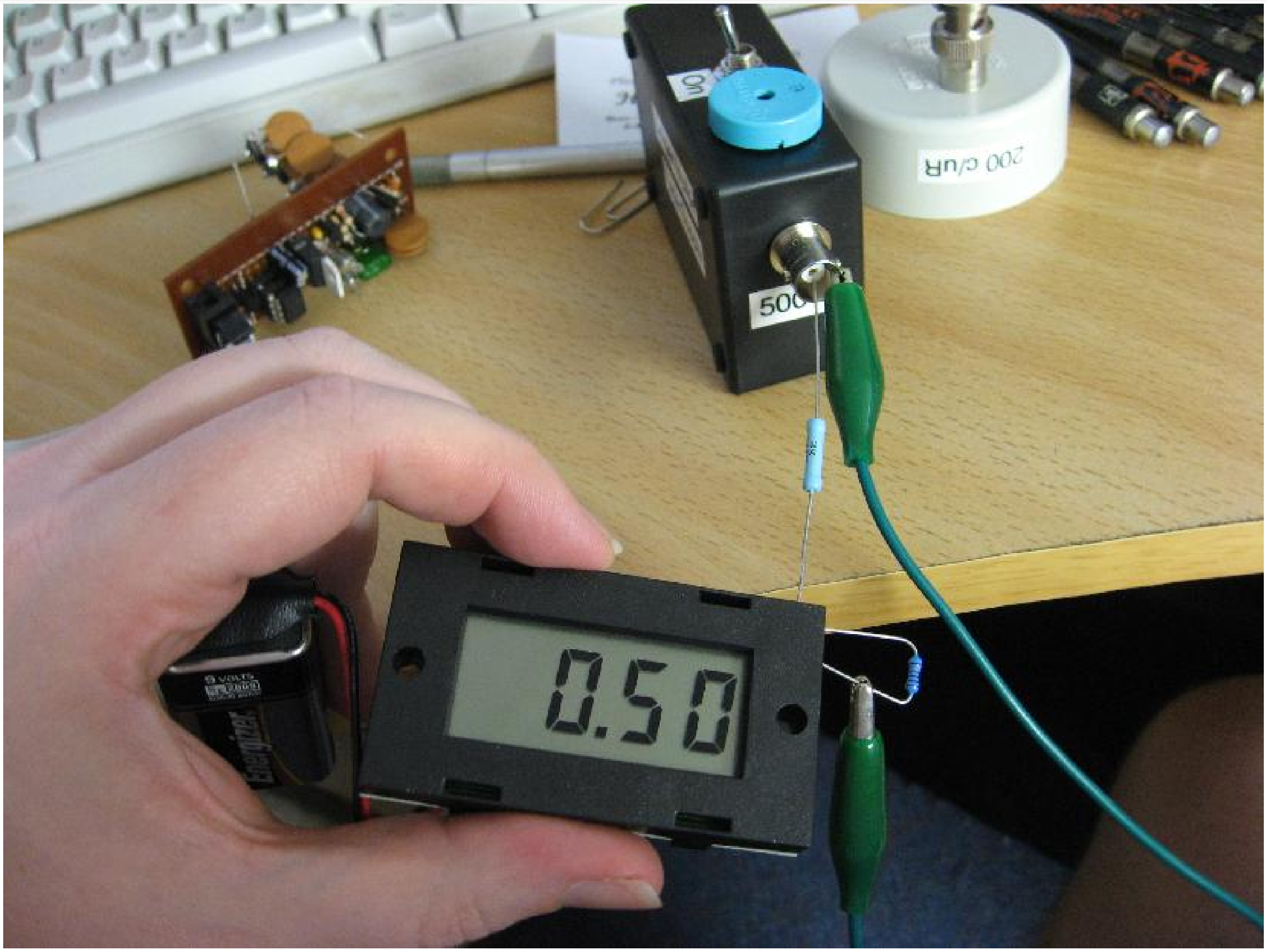
With the end window being quite transparent you can easily see the discharges in the tube caused by the ionisation radiation. While not particularly localised (the plasma sheath expands rapidly by secondary ionisations in the avalanche) it is a bit like a spark chamber, showing you roughly where the particle passed through the detector. I quite enjoyed observing the flashes in the dark, it is a bit like a spinthariscope, only with much brighter diffuse pink flashes. I tried to capture the effect on video, but wasn't very successful.



Video of the GM tube discharge flashes in the dark
(4.934 Mbytes)

Initially I used the circuit I built for the previous tube, but I decided to build a smaller portable version I could use a "survey meter" - there are some Coleman lamp mantles at Big-W I want to determine are Thoriated or not... A new inverter was constructed on a scrap of PCB material. I tried a different 10 mH inductor from the junkbox this time and found it worked better than the unit I had used previously. This let me use fewer multiplier stages for the supply, the circuit ending up virtually identical to Charles Wenzel's, except I used a protective gas-gap tube (from Rockby's clearance sales) for the regulation string and picked off the voltage at the last multiplier stage. This gives my unit excellent regulation and I lucked out that the tube gives almost exactly 500 volts in the circuit. (Open-loop the device delivers 783 volts.) The 3-pin transient protection tube is designed to be placed across telecom lines and features a 350 volt breakdown from each line to earth. It just so happens the breakdown from line to line is about 500 volts - perfect for my purposes. I originally grabbed them for a crazy idea of using them in Marx generators as a substitute to spark gaps or avalanche devices, but I am yet to try that.

To measure the very high impedance output of the supply I threw together a simple instrument using a 1 GΩ resistor and a commercial 200 mV FSD LCD digital display module. The module came from Rockby and has an input impedance that exceeds 200 MΩ, but I am shunting it with 10 kΩ so in relative terms it is quite insignificant. The 1 GΩ resistor I got from Farnell, and cost a ridiculous $8.40. It is rated to 5 kV, but I've tested it to beyond 15 kV. I arranged the meter decimal point so it reads directly in kV, forming a 20 kV FSD meter, but I wouldn't trust the single 1 GΩ resistor at 20 kV. I've used it to measure 15 kV sources however. I killed one of my favourite multimeters trying the same thing at 30 kV, so I am hesitant to push my luck much further until I build a similar device with good insulation and protection devices across the divided output.



Anyway, the resulting radiation measurement instrument is not calibrated in any way and offers just a piezo clicker for registering tube counts. I intend to add a count-out jack and probably interface it with a microcontroller driven LCD. The tubes came with sufficient information to roughly calibrate the device (about 200 counts per micro-Röntegen for Cobalt-60 gammas).

It fits the bill for a compact activity sensing unit I can take down the mall and check out the Coleman mantles with. Here is a video of the unit clicking away to the beta emissions of the small Potassium 40 content of natural Potassium Chloride.

GM detecting Potassium-40 emissions
(2.894 Mbytes)

The sensitivity of the tube is quite excellent. Without integration the emissions from the KCl are easily missed when using the old end-window tube. With the pancake tube they are quite obvious to the ear alone. The supply will work just fine with the older tube which is handy, and I've re-plugged it with a BNC to facilitate quick swapping.

12 comments.

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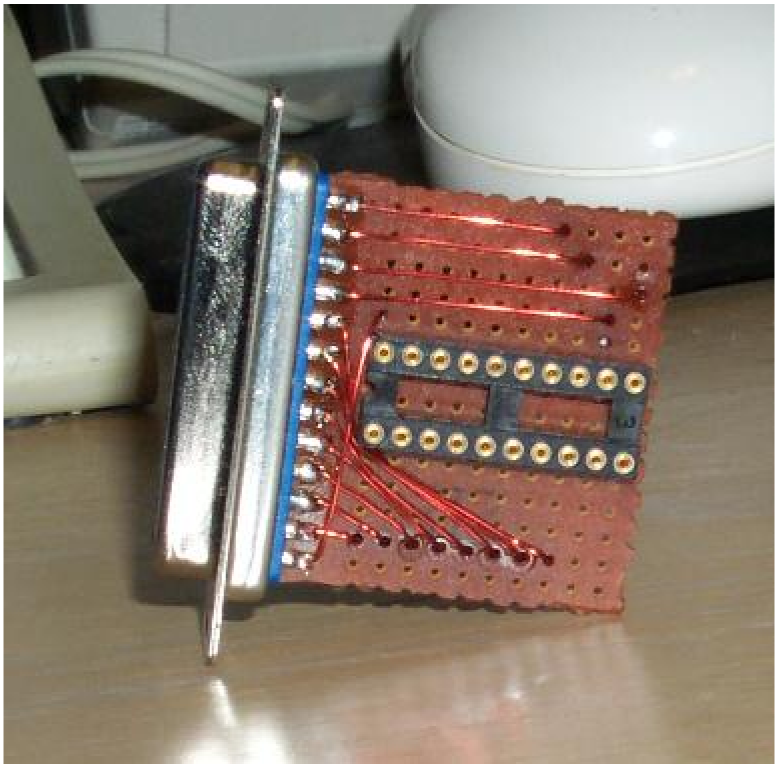
Parallel Port Breakout

2003-07-11



One day a fair while ago I built this prototype parallel port breakout widget after spending a few frustrating hours working with the arcane pin-out of the PC parallel port.

It probably isn't a new idea, and it probably isn't really that earth shattering, but I find it much easier to work with the signals lines brought out in the same order as their respective bits in the registers that represent them. At least when I am probing around with a logic probe while debugging.

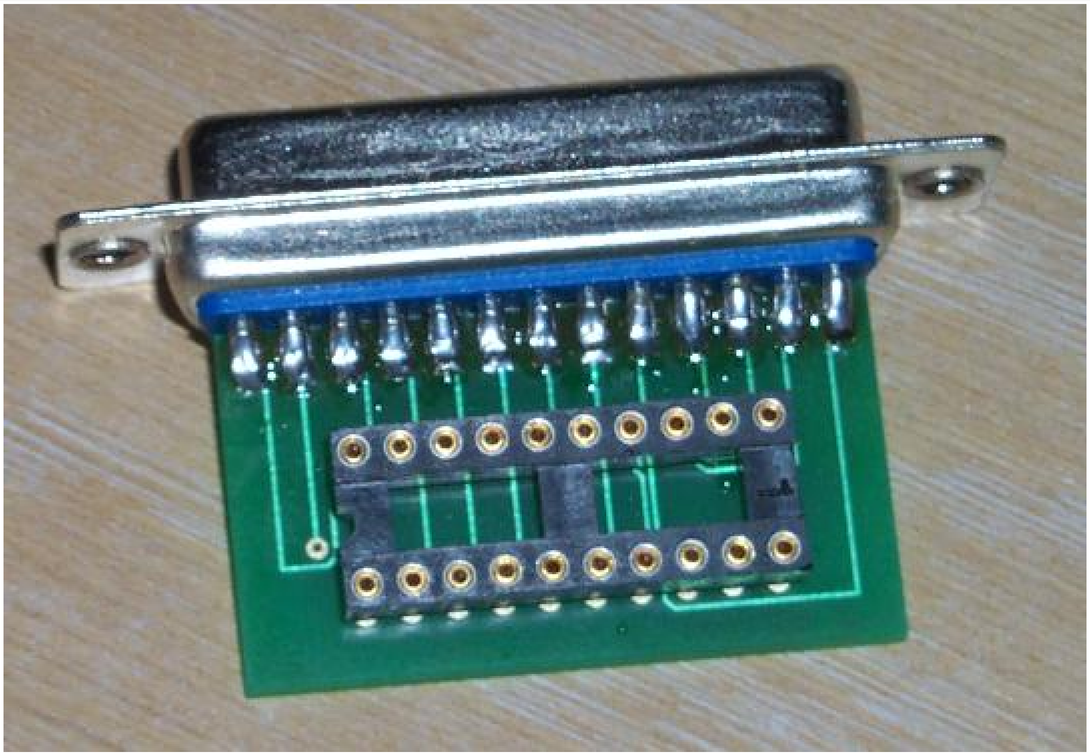
The prototype was built using some fine gauge enamel wire and about an hour of patient soldering. You can build your own pretty easily, but it is time consuming. After extensive use of the little tool I showed it to a few people and they loved it, vowing to build their own.

The idea, for those unfamiliar with the practice of using machined-pin IC sockets as transient connectors, is to use a piece of *solid-core* (single strand) hook-up wire to plug into the socket and then into your prototype on a solderless breadboard. I find the wire from cat-5 cable, or old PC data leads ideal for this kind of service. A pair of side cutters and a *T-Rex stripping tool* is an excellent rapid bread boarding combination. (Sourcing 0.71mm solid core PVC jacketed wire is increasingly difficult and expensive compared to flex hook-up wire, at least in my neck of the woods.)

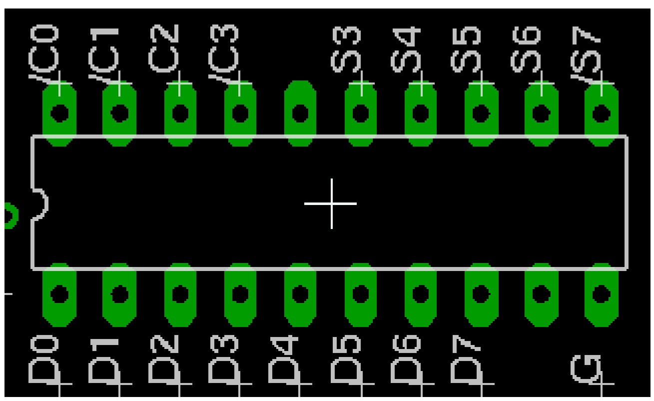
I decided to get a small PCB made up to make building them trivial. I figured, worst case, I can probably flog them on eBay if my idea turned out to be totally insane.

Unfortunately the first batch I got made up were missing the silkscreen because the board house's machine broke down and they sent them anyway, believing I was in a rush for them. This is a little annoying, but doesn't make the entire batch worthless. I am selling them on eBay at cost. I've since received a replacement batch from the board house with the silkscreen which will also be sold to friends and on eBay.

Here is a picture of one without a silkscreen:



The pin-out is easy to learn and remember:



The leading / denotes signals of inverted logic (i.e. active low, a 0 in software is 5 Volts in hardware). The PC parallel port is represented in software as three 8 bit IO locations. For the first port, the IO base address is 0x378. Various signals, both input and output and inverted in the hardware of the PC port, this breakout is completely passive, doing nothing to 'correct' this, it simply notes it in the silkscreen and lets you deal with it in your application hardware (or software).

The first register (i.e. 0x378) is the Data or D register. By default it is an 8 bit wide output. This breakout maps D0-D7 to pins 1-8. By setting a bit in the Control register you may turn these pins into 8 inputs with weak pull-ups. There is no facility to do bit-wise I/O selection, it is all 8 bits at once or none. At least for the SPP mode. Input (bi-direction) may not be supported on some older ports, but all modern devices claiming to be SPP compliant will offer bidirectional mode. The pins can source several mA, and can light a LED via a 560 Ohm resistor to the DC return/ground, which this breakout offers as pin 10.

'''In fact I've made up several strips of LEDs with dropper resistors on a piece of IC socket or SIL header. It is very handy for viewing byte-wide bus states, or general bit states from a prototype. If you are fortunate enough to come across an IC test clip you can make a buffered parallel logic probe.'''

The second register (i.e. 0x379) is the Sense or S register. It offers 5 inputs, mapped to the 5 MSB of the register. The MSB (S7) is inverted. The inputs typically offer weak pull-ups in hardware, but I've seen many ports that are a bit weird in this respect, in particular many Toshiba laptops have truly bizarre parallel ports. The bottom 3 unused sense bits seem to always read 1 in SPP mode, but I wouldn't depend on it.

The third and final register (i.e. 0x37A) is the Control or C register. It offers 4 outputs mapped to the 4 LSB of the register. All are inverted except C2. The output will source a few mA and are much like D0-D7, some are defined to be open collector, but all modern ports seem to ignore this. The C5 bit is special, setting it enables

enables interrupt generation, the IRQ associated with the parallel port (i.e. IRQ 7) will fire on the rising edge of S6. C6 and C7 seem to always read 1 in SSP mode, but again don't depend on it.

Strange things to watch out for are ports that tri-state after each read, or only assert D0-7 while the Strobe signal is asserted. This is totally broken, but not uncommon on cheap 486 I/O cards and laptops.

This site has a huge collection of parallel port information. It also carries lots of Win32 specific software and links, which is something I can't help you with :-).

I've also written some software for Linux to help with prototyping with these things. It is very simple, it offers a few commands to print the state of the parallel port registers, toggle or set individual bits, and set entire registers to decimal, hex, or octal values. It is interactive, the ? command gives the command list:

```
Commands:
        q               quit
        ?               this usage message
        r               Read status of port
        d <byte val>    assign Data register
        D <bit num>     toggle bit of Data register
        c <byte val>    assign Control register
        C <bit num>     toggle bit of Control register
```

Byte values can be supplied as decimal (e.g. 34), octal (e.g. 042), or hex (e.g. 0x22).

In Linux you need to be root to call the ioperm() system call (giving a user space process access to IO space). You should setuid the tool and only allow your development people's group to execute it. You may of course just run it as root, but setuid is nice. It isn't written to be super secure, it is a development tool, not something you'd have on a Internet facing server. #include <std-disclamer.h>

Some ideas to get you started? How about bread boarding my I2C Interface/Serial EEPROM programmer, or how about testing some stepper motors with something like this code and this circuit (I've used this many times, works great for small steppers from fax machines, scanners, and disk drives. Use more voltage for more torque, you will warm up, but not destroy 5 V steppers running them from up to about 18 Volts, just don't leave them sitting there burning, share the current around the windings, or add resistors.). Two steppers can be controlled via one port in this manner, for example, to move an X/Y platform. Perhaps some other 2 dimensional control system. Limit switches can be read via the Sense bits. Perhaps the Control bits can turn on machines, maybe a vacuum clamp, maybe a Z-axis stepper. CNC here we come :-)

Leave a comment on this article.

Pedometer with Morse Interface

2008-05-04

This project was inspired by the death of my current pedometer's battery. Being too lazy to find my box of LR44s buried somewhere in my junque box, I decided to implement my own pedometer. Longer term I have visions of storing biotelemetry into a serial EEPROM for later analysis (making it a more useful device than the current cheapy commercial unit), but this initial proof of concept is just a step counter.

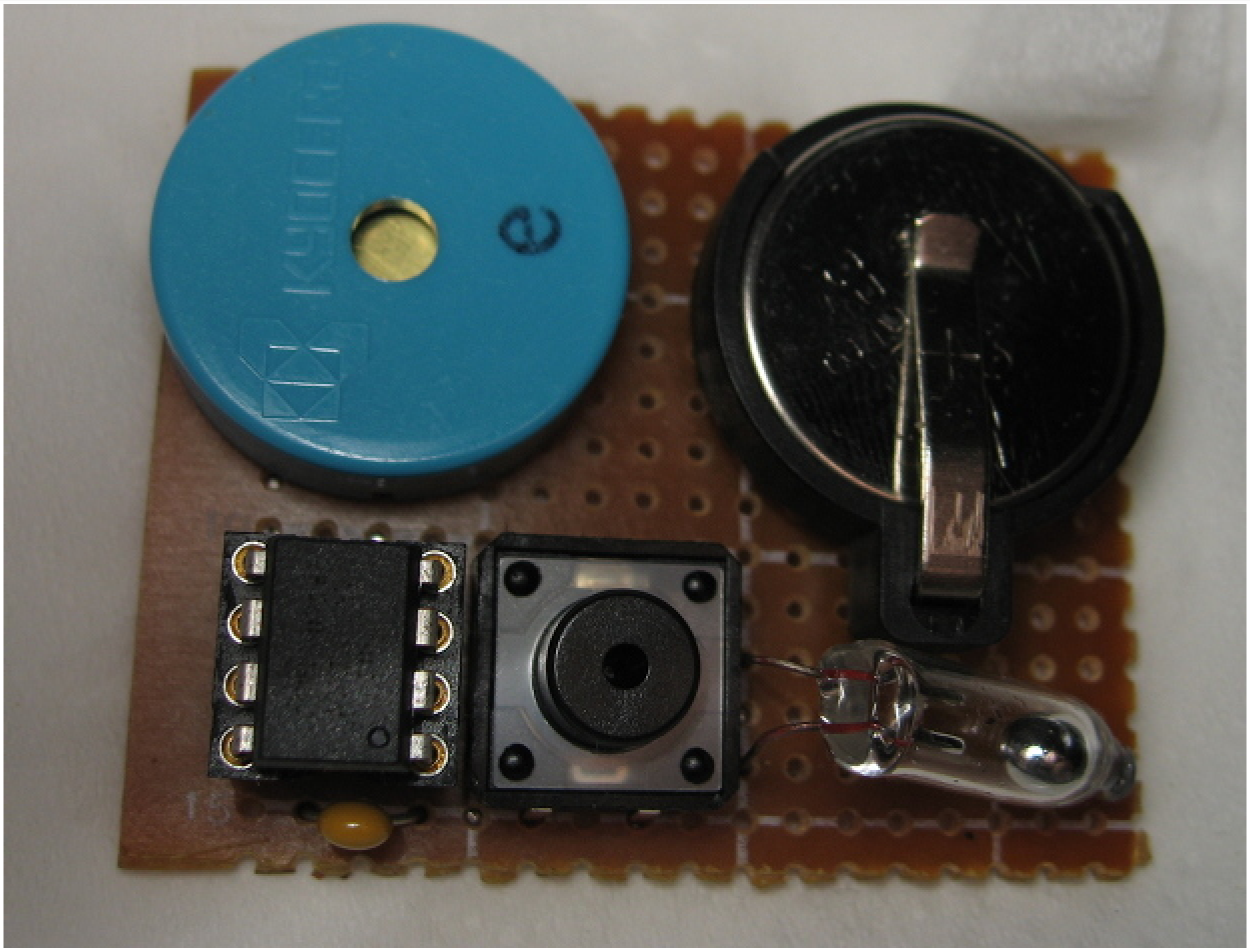
The concept was scribbled in my notebook on the evening Ferry trip home for work last Monday, shortly after I noticed my commercial pedometer was dead. Unfortunately I didn't get a chance to actually work on the project until the weekend, but once I started it only took a few hours to get going - I'd had almost a week to design it in vivo.

Yeah, but Morse Code?

Using Morse Code as the interface was from the realisation that it was fairly easy to implement, consumed very little power and took only one drive pin (compared to the three required to charlieplex LEDs for a 6-pixel POV display - a future project no doubt). Usability might be a problem, but it is also a good excuse to drive me to learn CW properly, the numbers are easy and I think even complete CW novices would learn to read it quickly. No doubt such a device might be good for the vision impaired.

Hardware

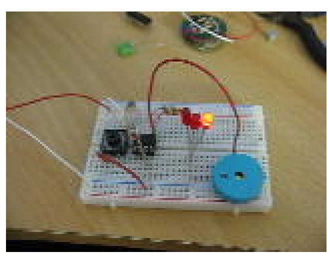
The interface is simple, a Mercury switch as a footstep detector, a button which you can press to request the current count be squeaked out in Morse Code (through a piezo) or held somewhat longer to clear the count back to zero.



The brain is a ATtiny13V MCU, sourced from Futurlec. Power is from a CR2025 Lithium battery which was found on my desk and for which I just happened to have a bag of battery holders from a recent Rockby clearance. The same Rockby order also supplied the Hg switch, button, and the piezo. The only other component is a 100 nF decoupling cap across the MCU.

Smaller components could miniaturise the unit a lot, the piezo, battery and switch in particular are quite large, but an SMD tiny13 is available too.

Here is a video of the prototype being tested:



Prototype Under Test
(5.878 Mbytes)

Software

The MCU spends most of its time sleeping powered-down. Asynchronous pin-change interrupts wake it for a footstep transition or the button. Footsteps are de-bounced before counting and have a lockout period to limit the transitions to physically likely frequencies (about 5 Hz max which is reasonable for human cadence rates). The counter is incremented, then straight back to sleep after toggling the piezo drive line (generates a quiet click). Button presses are debounced in a similar manner and then decided between a press and a longer hold, which drives either a display action or clearing of the counter.

The Morse Code is stored as 2 bits per symbol. This is a standard I've used in beacon code in the past, in fact I put the full code in there for handling char and word spaces even though it isn't used. I am considering adding an interactive menu so it might be needed in future. In the current application I actually only need one bit for

spacing is constant). There is still a bit of ROM left so I could shrink the CW associated code and put in another feature that didn't need Morse, perhaps I2C support for data logging.

All the timing intervals and frequencies are set by #defines and are easily tuned to the user's preferences. The 800 Hz morse frequency is a bit low for efficient drive of the pizeo used, its resonant frequency is about 4 kHz. Lower frequencies are more traditional for CW, but higher ones sound cleaner because of the reduced harmonic content. I picked 15 WPM as a good beginners rate, but 25 might be better as you are tempted to count dits and dahs at only 15 wpm.

I did have a little stack-smash problem with the software that took some figuring out. I was simply running out of stack because of the number of frames I had in the execution trace. Some code revision fixed it, in particular moving the decimal magnitude array into ROM, originally I was creating it on the stack - all 10 bytes of it! I also reduced the size of some loop counters to save a bit more when they were pushed. I was at one point going a bit nuts though, I even compiled the same algorithm with gcc to prove it was OK on the "big machine". The experience made me investigate the standard toolchain utilities much more closely, in particular avr-nm and avr-objdump. Reading the assembled output of avr-gcc is always helpful in such a situation. The compiler is very good, but looking at what it generates I know I could do a little bit better by hand if I ever need to really squeeze more into a small device like the tiny13.

The source is here.

Battery Life

The two internal weak pull-ups probably dominate the current consumption. It takes about 90 uA sleeping, 1.3 mA while sounding. The CR2025 has a capacity of about 150 mAh so I'd expect about 2 months battery life with modest use. This could no doubt be improved.

2 comments.

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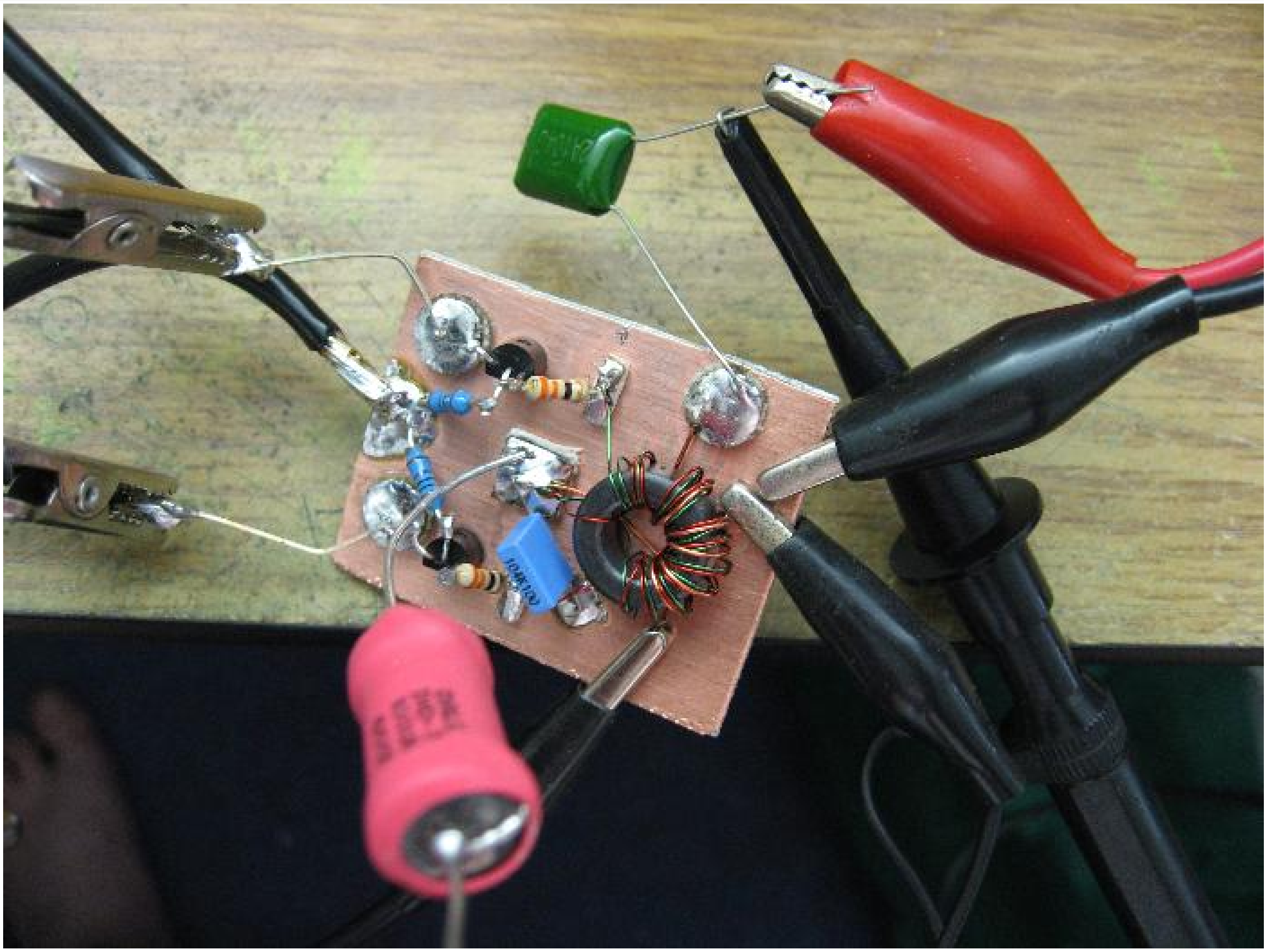
Phantom-Powered Active Loop Receive Antenna for 30 Metres

2010-03-27

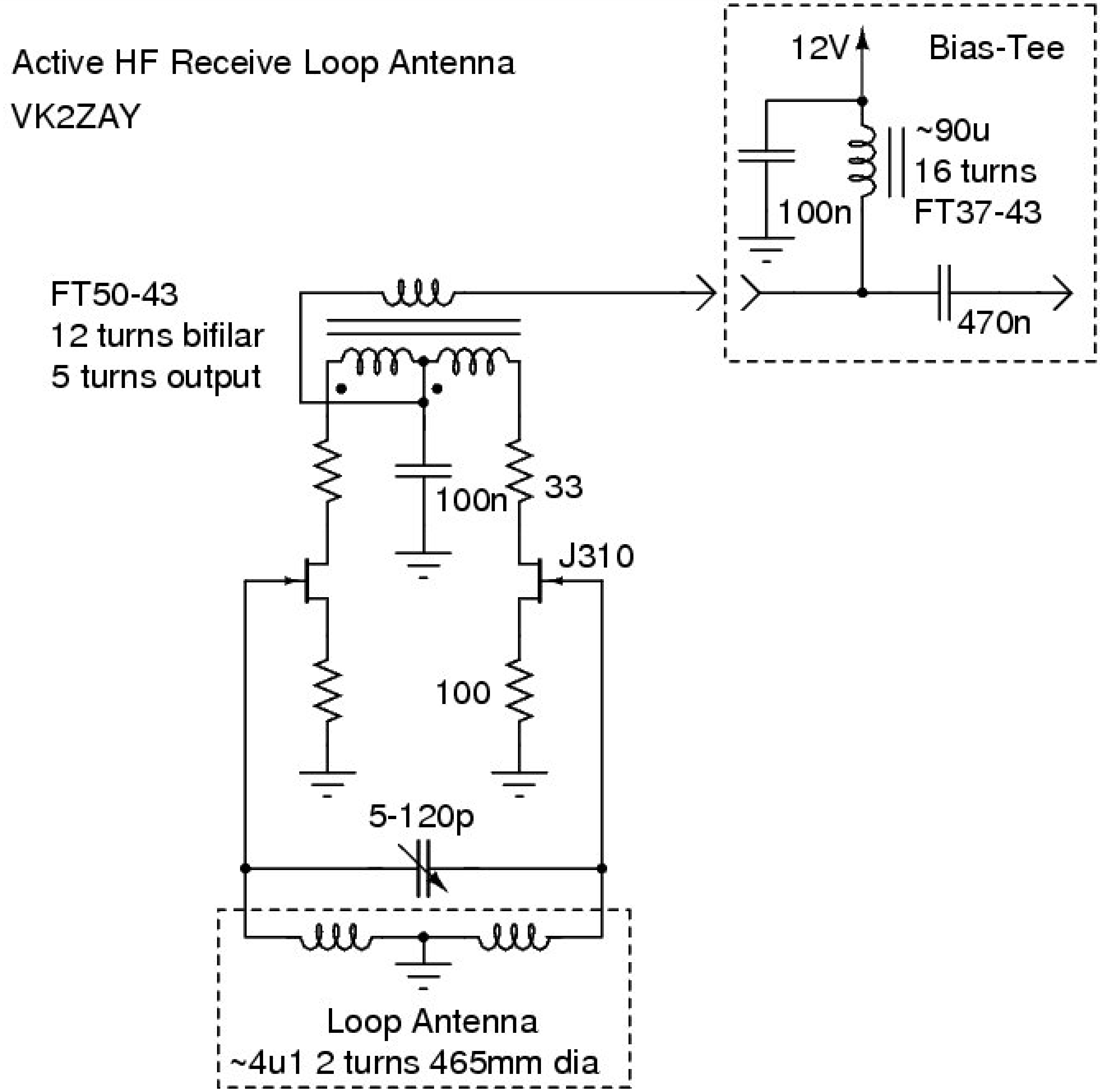
This loop antenna was built for 30 metre QRSS reception, but tunes beyond 30 metres and might be useful for general narrow-band (fix-tuned) HF work.

The Antenna

The loop is two turns of ~3 mm multi-strand hook-up wire, wound on a large (465 mm diameter) embroidery frame. The coil is centre-tapped, and referenced to "ground" at that point. A polyvaricon tunes the coil to resonance at the frequency of interest, and a push-pull JFET buffer amplifier transforms the very high impedance of the parallel resonant circuit down to something suitable for what is seen through the coax from the receiver (and also offers some power gain at the same time to offset feed-line loss). The buffer can deliver a relatively large amount of power, in excess of 0 dBm. This should offer good strong-signal handling, but I have not measured its IP3.



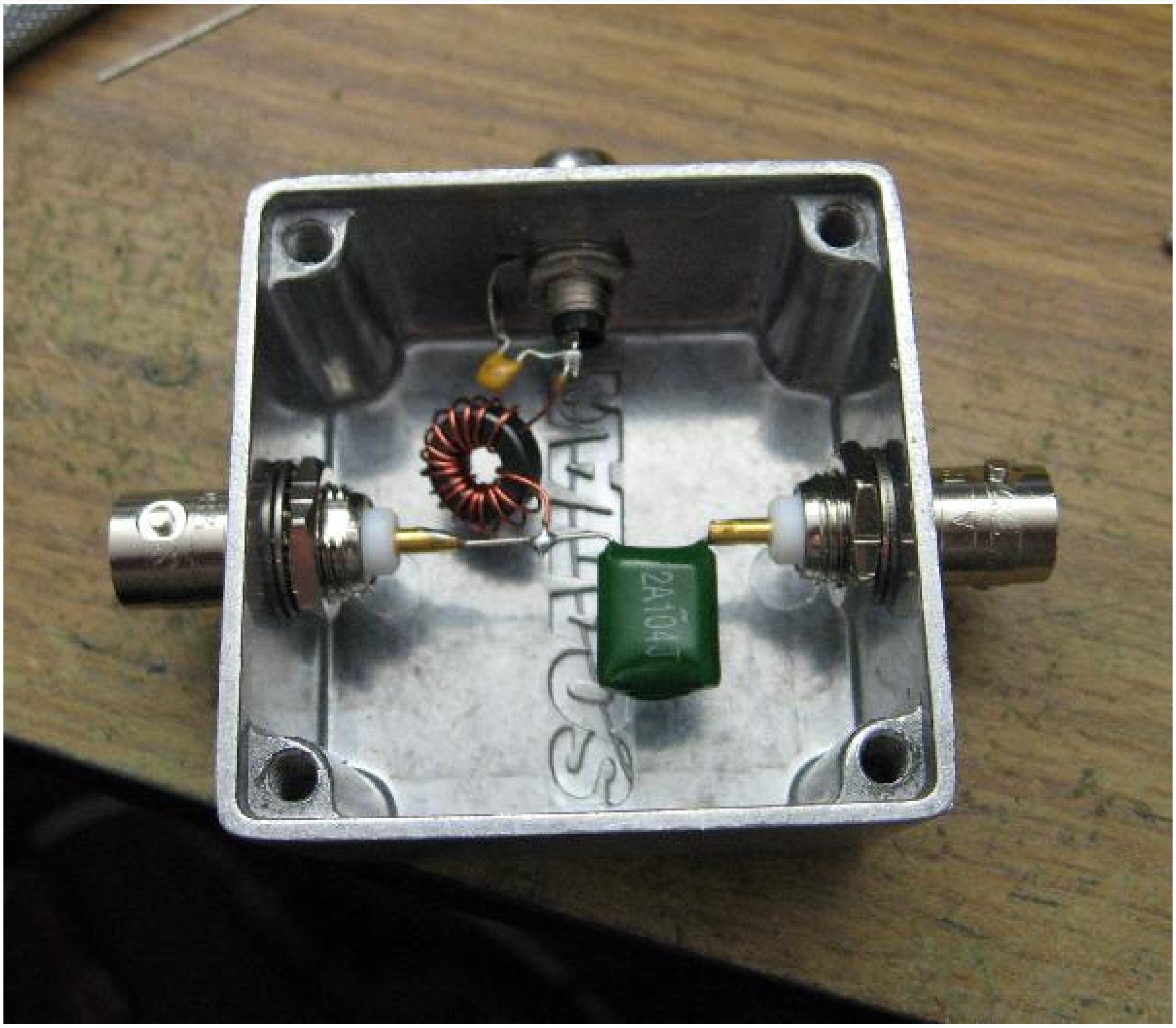
Each J310 stands about 2.5 mA. I hand-picked a pair of well matched J310s (by Vpp and Idss), this is likely unnecessary but it can't hurt to ensure each arm has similar biasing and gain to optimise the distortion cancelling effects. The 33 Ohm resistors in the drains help eliminate any tendency for spurious oscillation. The supply current feeds into the bifilar drain loads from the decoupled "cold"-end of the output winding, using it as a choke. This seems to work well in practice, with no visible distortion asymmetry (when over-driven) from the DC bias on the magnetics. (The standing currents in the bifilar winding cancel, but those in the output secondary do not, fortunately the supply current is only about 5 mA so this should be of no consequence. As long as the transistors saturate well before our ferrite core - an FT50-43 - we are in good shape.)



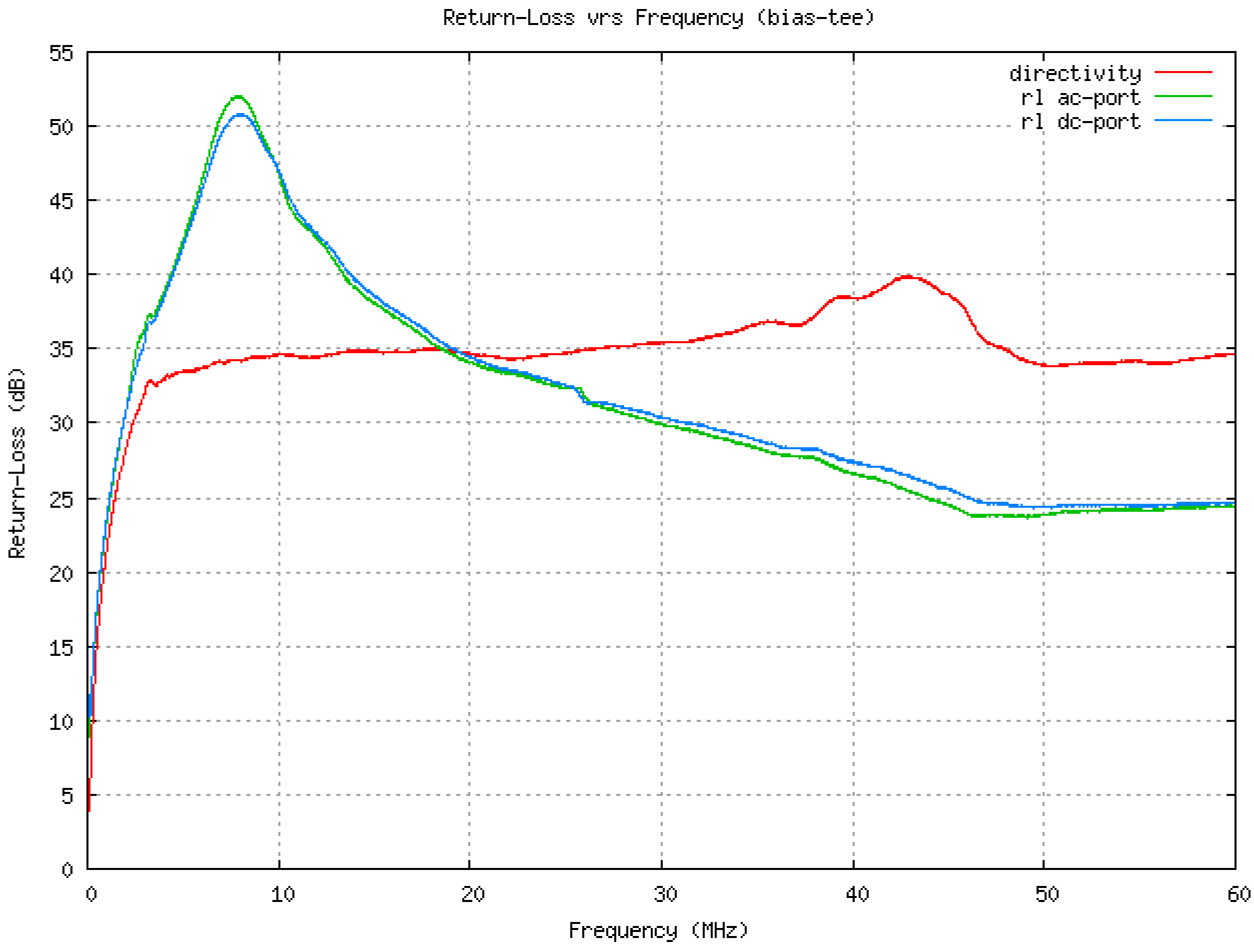
More gain is available by bypassing the 100 Ohm source resistors. Oscillation can occur with excessive gain. You can set the gain at a higher, but stable level by adding resistance in series with the bypass capacitors.

The Bias-Tee

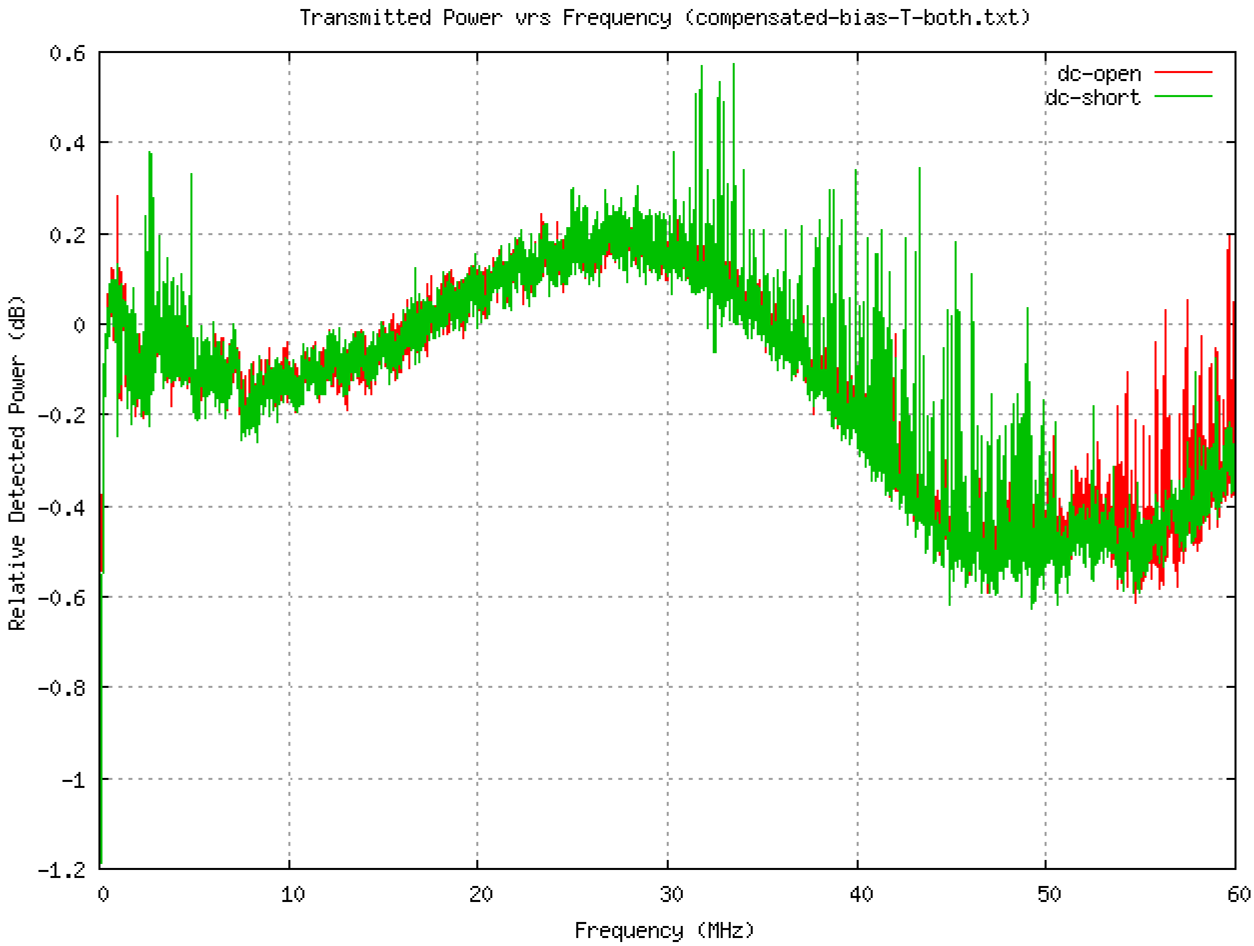
To feed the DC supply to the antenna at the shack-end of the coax a simple bias-tee was constructed. As the frequency of operation is only mid-HF a simplistic ferrite toroidal choke and two capacitor affair was constructed in a small die-cast box. I was confident this construction was sufficient at the frequency of operation, but curious about its performance elsewhere, as such it became one of the first test subjects for my experimental scalar network analyser.



Despite having very poor "design hygiene" for high frequency response, sweeps of the bias-tee with the analyser suggest it offers acceptable performance across HF. There are some oddities in these measurements however. Fortunately they appear to be measurement equipment problems rather than excessively nasty behaviour of the device under test:



Note how the measured "return-loss" exceeds the bridge directivity below 20 MHz. This is of course an illusion, caused by the small stray reactances of the bias-T conjugate matching the bridge for better than calibration reference balance. Ideally I should change the graphing software to compute error bars based on the reflection signal magnitude compared to the directivity established by Open-Short-Load calibration at the same frequency. As the directivity of the bridge exceeds 30 dB above a few MHz all the way to 60 MHz we can safely say the bias-Tee is an reasonable match over the same range displaying a return loss exceeding 20 dB the entire way.

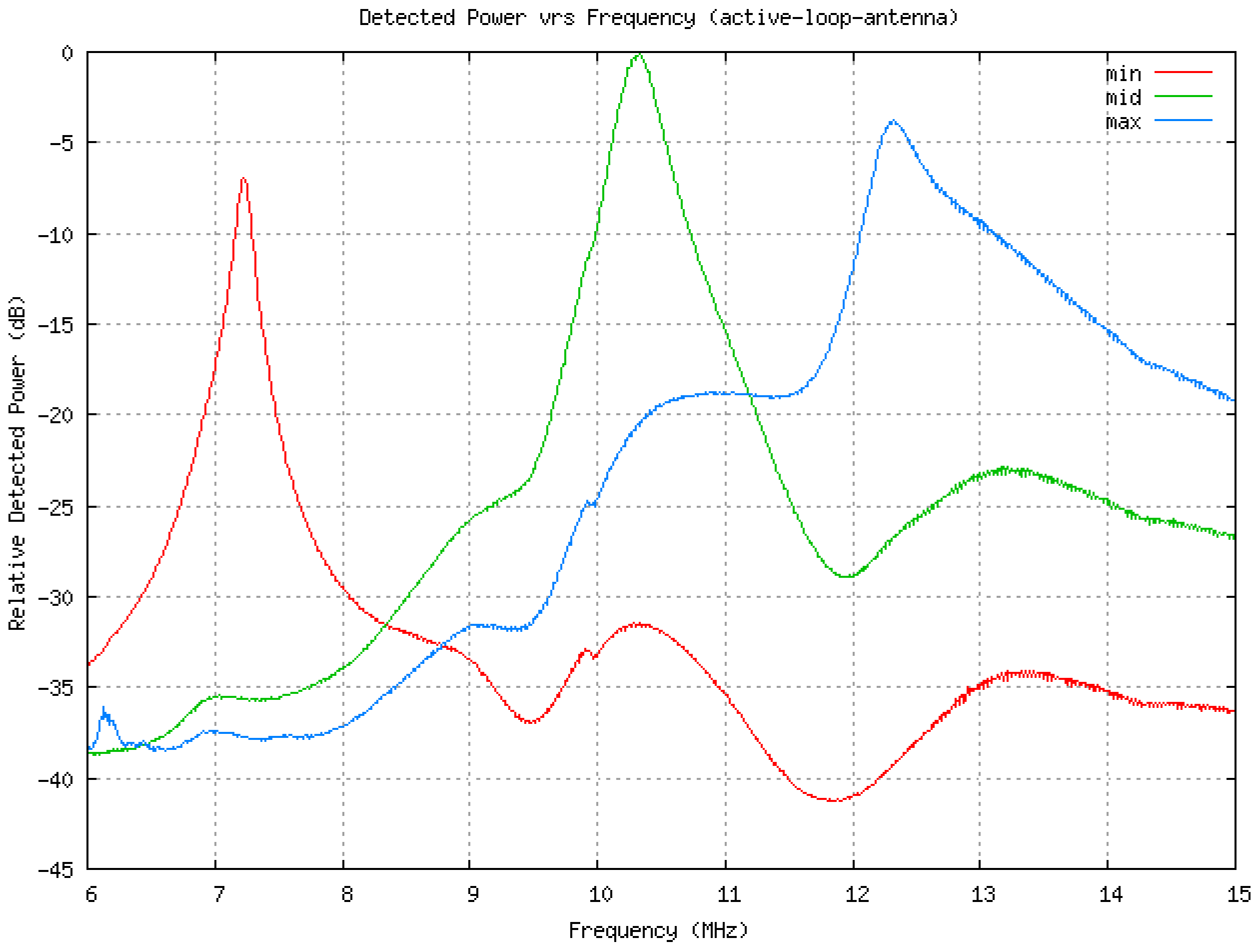


Transmission measurements similarly have some weirdness. Despite the test setup having 20 dB of attenuation in the signal path the bias-T performs the miracle of over-unity performance. Of course this is not real! Again it is just conjugate matching something in the system to make the reference calibration invalid. The variation is only a fraction of a dB so for all intents the bias-T is near-perfect across HF and into low VHF.

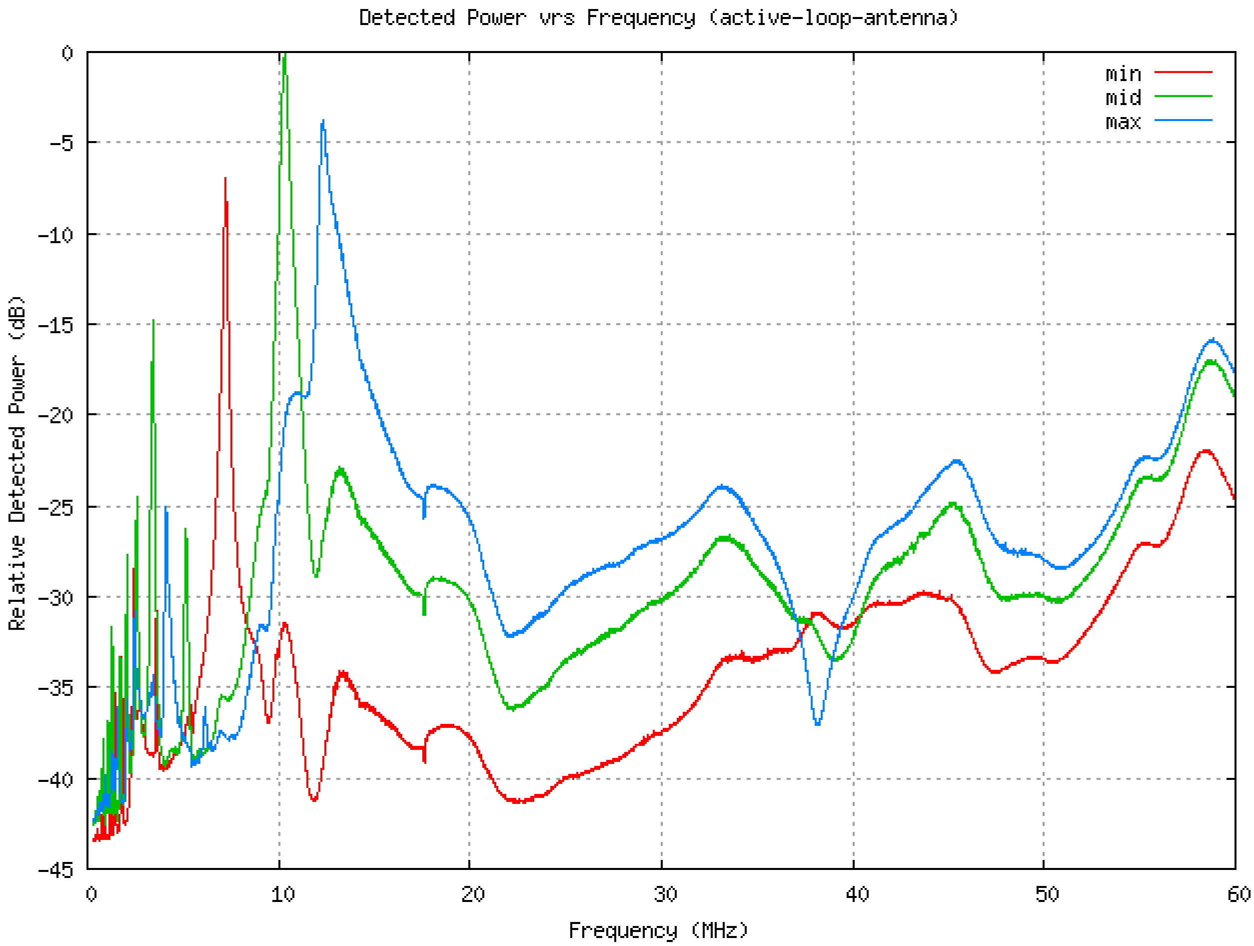
Lab Testing

It is rather difficult to lab test a loop antenna in a reasonable way. In particular it is extremely difficult to immerse it in a RF field of sufficiently controlled spatial uniformity and consistent amplitude with frequency to make absolute and repeatable measurements. For my initial testing a 100 mm diameter coupling loop was connected to the signal generator and loosely coupled to the antenna loop. Sufficient drive was applied to achieve a few dBm out of the loop buffer and into the power meter at peak of resonance. This allowed crude measurements of bandwidth and amplifier compression.

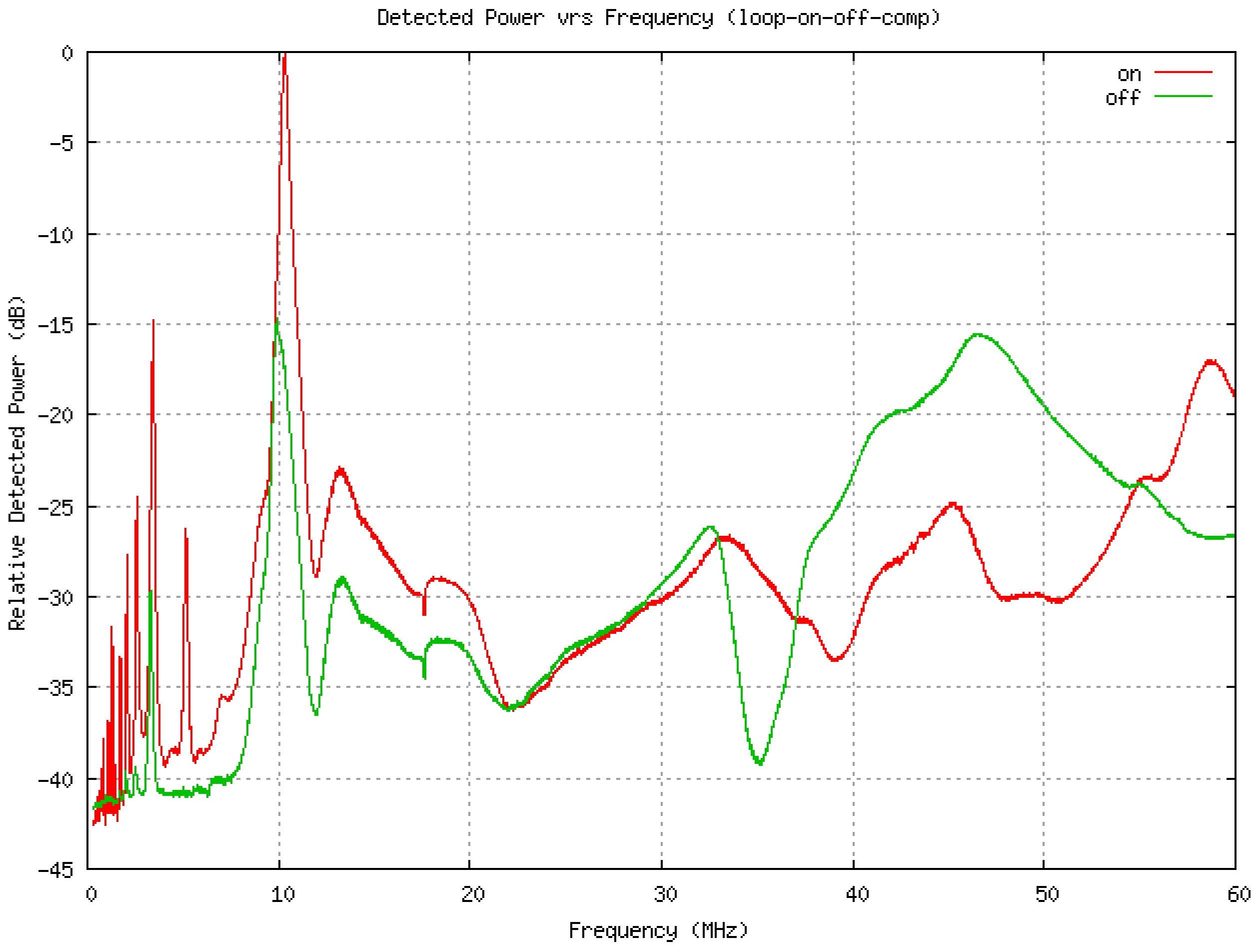
More detailed investigations were made by sweeping the unit with the same experimental scalar analyser used to test the bias-tee. Exact amplitude measurements made in this way are fairly meaningless, as the coupling loop is not well matched to the generator. 10 dB of padding was placed between the coupling loop and the generator but as the loop was placed almost orthogonally to the antenna loop to provide weak coupling (for Q estimation) the coupling loop does not see much of the antenna loop loss resistance.



The loop tunes 7.23 MHz to 12.32 MHz with the polyvaricon used. The apparent loop Q drops with frequency, being 55.6 at 7.23 MHz, then 33.3 at 10.33 MHz and 28 at 12.32 MHz. The loop inductance is about 4.1 uH so the input impedances which match these Qs are 10 kΩ, 8.8 kΩ and 8.9 kΩ respectively. Wider sweeps show problems with the test set-up, in particular generator harmonic energy when tuned below the loop resonances. Neither sweeps have me feeling very comfortable about the quality of test set-up (or the loop construction for that matter). The HF feed-through is probably due to the unshielded housing of the buffer amplifier and stray circuit capacitances. Maybe a LPF should be added to the output to suppress these responses? A HF receiver should reject them with no dramas, but the number of hints of internal resonances and general "complexity" of the baseline above and around resonance doesn't make me too comfortable.



When the amplifier is left unpowered the loop leaks through RF at a lower amplitude, and the resonance is shifted down in frequency somewhat. This is immediately apparent when you connect a receiver to the loop, even without powering it on you can peak-up the background noise level by tuning the polyvaricon. However once power is applied the loop must be retuned (up somewhat) for maximum background noise. Loop Q is degraded quite significantly in the leak-through mode, with Qs of 39.3, 17.1 and 9.1 for the test frequencies discussed above. Loop Q in general could be improved by weaker coupling to the JFET gates, some simulation could optimise the values required if the resonator usable Q was measured and the FETs well characterised. Noise figure would be compromised by resistive DC gate biasing, maybe use chokes?



On thing I initially found rather disturbing about this particular sweep is the 2nd harmonic peak is absent from the "off" run. The 3rd harmonic peak is 15 dB different just as the fundamental is - but the 2nd harmonic "on" signal is smaller and 15 dB down from its level is into the -41 dB "leakage floor" we appear to be observing... All was revealed when I considered that the reference level here is about -12 dBm meaning the leakage is around -53 dBm, quite likely considering the unshielded nature of the amplifier in close proximity to the coupling loop.

Field Testing

For real RX testing I lashed-up the antenna on the balcony, mounted a little above railing height, and A/B compared it against the base-loaded vertical I use for QRSS transmission. This is *not* a very fair test, as the vertical is 3 metres tall, while the loop is less than half a metre in diameter and was mounted at the base of the vertical. Also, interaction between the antennas was *not* controlled during the experiment, and experience has taught me this is critical for meaningful results.

The loop is largely limited by its aperture (cross-section). Compared to my loaded vertical it is about 6 dB down, making it ineffective for its original design purpose (improving my QRSS RX noise floor). However, unlike the omnidirectional vertical it has well defined nulls which are useful for avoiding local interference. The nulls do help dodge some noise, but unless I make it larger or mount it higher the loop is simply not as good for QRSS RX.

For comparison purposes I have built a much larger passive tuned loop antenna. The square loop is root-2 metres on a side in a diamond configuration (for mechanical simplicity) and is matched to the coax using a ferrite transformer placed near the polyvaricon that tunes the loop winding to resonance. It was not possible to fit the loop in the shack for Q-determination and hence the matching is at best an educated guess. Its Q is likely dominated by whatever the receiver input impedance reflects into the loop tank through the matching transformer. Experiments continue, comparing the three antennas for relative performance. More experience and additional test instrumentation is required before fair comparisons can be made.

2 comments.

Attachments

title	type	size

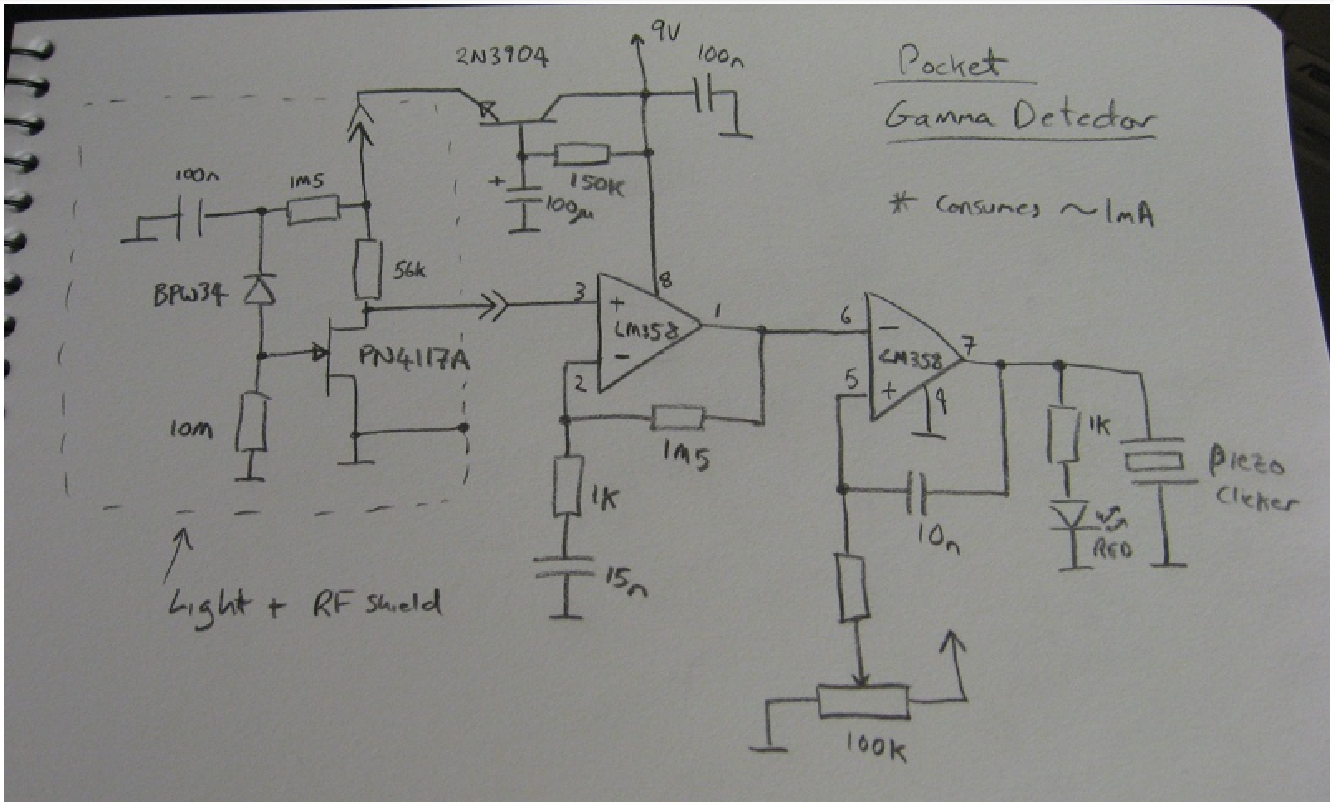
Active Loop Circuit Diagram Source	application/postscript	13.671 kbytes

Photodiode Gamma Ray Detector

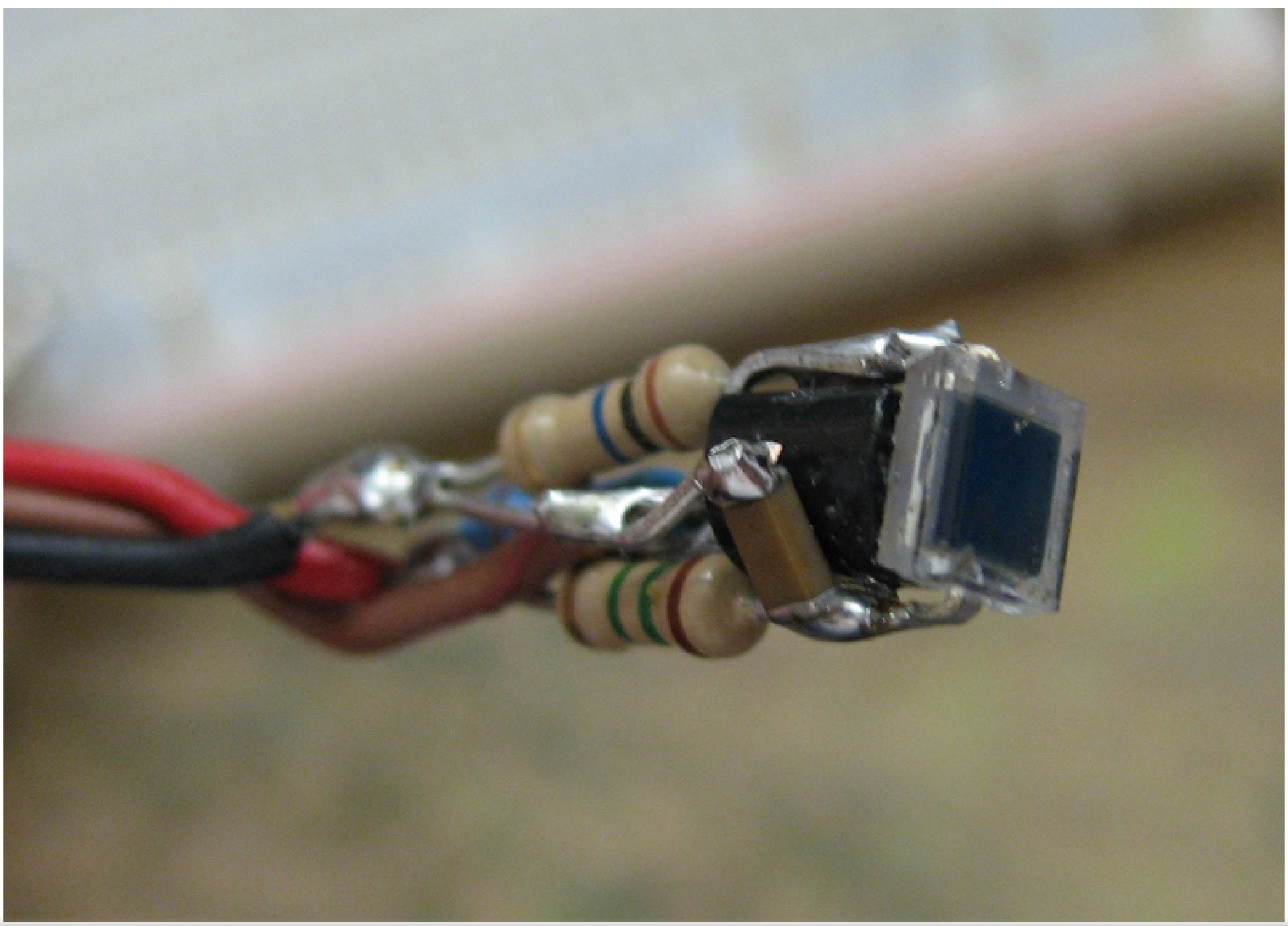
2011-07-10

Gamma photons interacting with cheap photodiodes produce small current pulses which are easily amplified and allow detection of individual photon events. This offers the possibility of cheap, small and rugged radiation detectors of reasonable sensitivity. While not as sensitive as larger GM-tube detectors, this solid state device is still quite useful for determining if something is radioactive enough to be interesting/concerning.

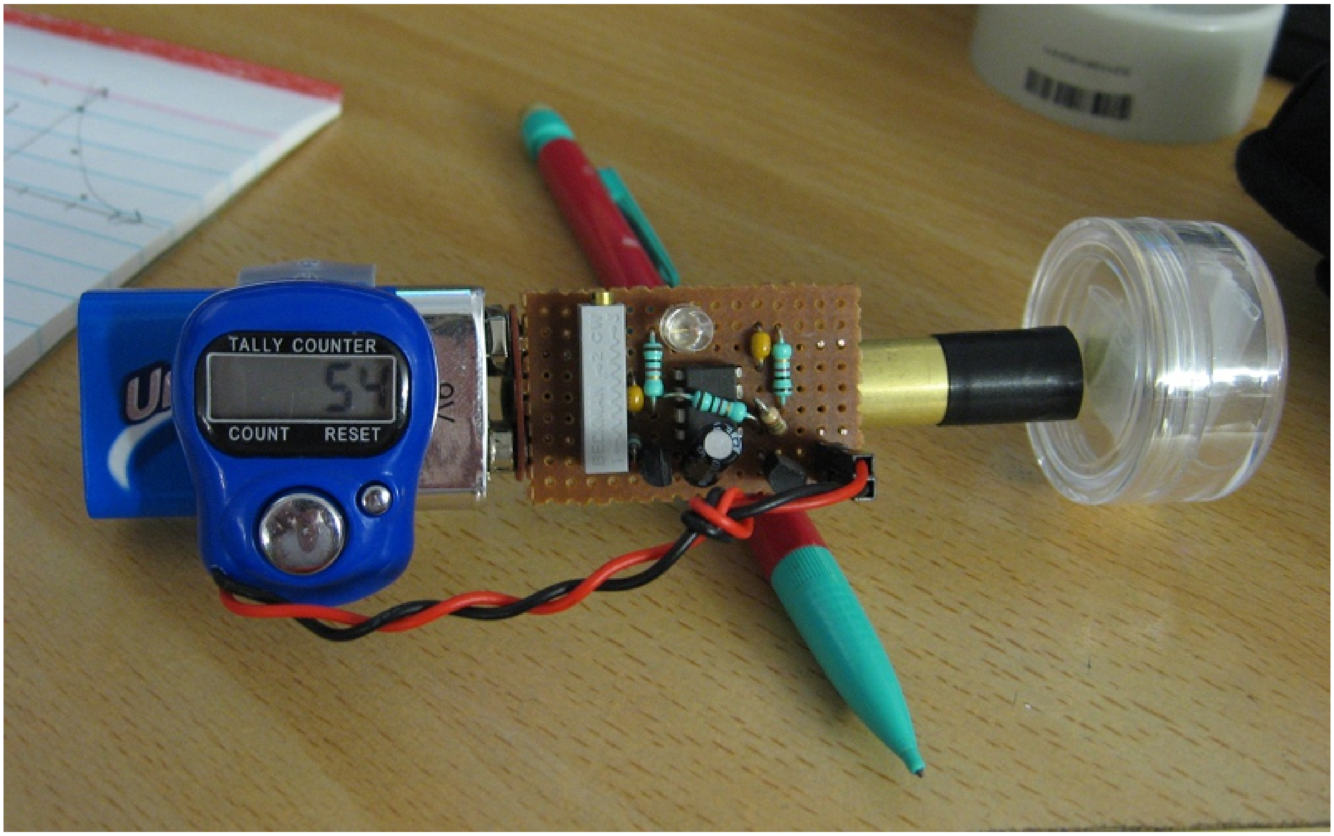
The circuit is simple, but as currently implemented has one major problem; poor temperature stability. As it is DC coupled right through to the comparator moderate temperature changes cause the threshold level to drift enough that the noise floor starts causing false triggering, or the sensitivity to less energetic radiation drops. Similarly DC shifts associated with battery voltage drop is also a problem. This is easily remedied by AC coupling the comparator stage. The unit shown has an extra output transistor driving the counter module, this is not required for the basic qualitative detector - it is implemented in much the same way as the counter interface of the ion chamber alpha counter. There is great similarity between the two circuits really, and one might build a dual gamma/alpha counter in a quite small package. (Note that there is also some sensitivity to higher energy beta.)



Construction is fairly non-critical. The sensor assembly was built using a mixture of SMD and through-hole components, with the BPW34 photodiode placed over the PN4117A JFET body. The completed sensor head was then placed in a small brass tube, with a thin piece of brass shim-stock foil closing one end to exclude light and offer some EM shielding to the sensitive front-end electronics. The other end was closed with wadding and liquid electrical tape. The detector module has three wires emerging from it and can be integrated with different electronics.



Spectroscopy *may* be possible with this detector, pulses do vary in amplitude, and appear to cluster around several similar amplitudes for different sources. However, the physical semiconductor sensor is quite small and no doubt only a small fraction of the energy of higher energy gammas is collected by it. It likely makes a very poor spectroscope, resolution wise, but it may be sufficient to tell apart the usual suspects, U, Th, Ra, and Am.



The background count rate is approximately a count every two minutes. The noise floor is quite close to ~59 keV gammas of Americium. This is probably the practical limit of the detector in its current form. More overall sensitivity might be achieved with additional or larger sized photodiodes. It should be possible to build large arrays with multiple buffer FETs all driving the one amplifier and comparator or pixelated detectors which operate like a gamma camera with seperate pulse detectors forming a matrix.

33 comments.

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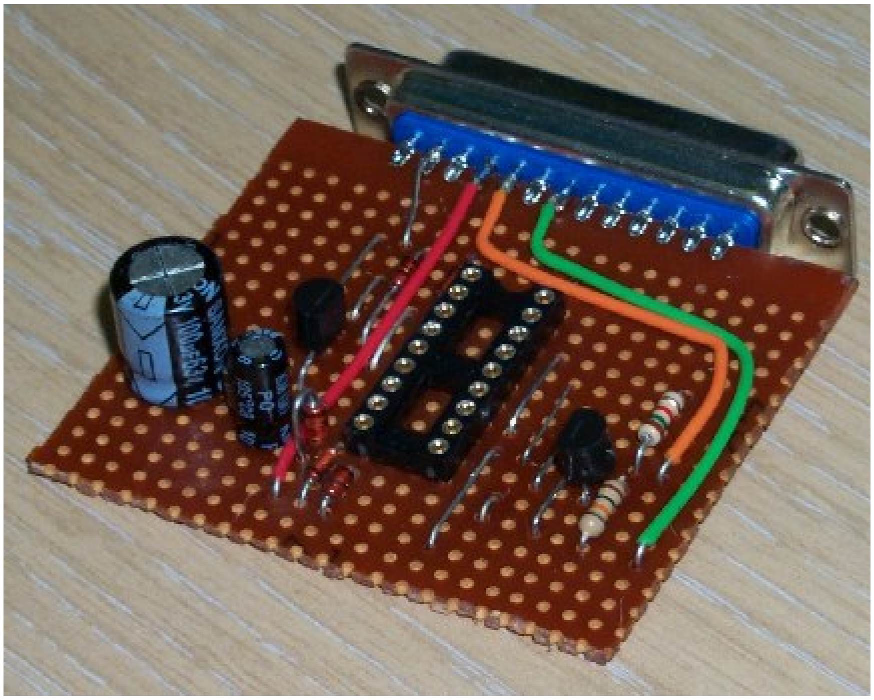
PIC Programmer

2003-04-13



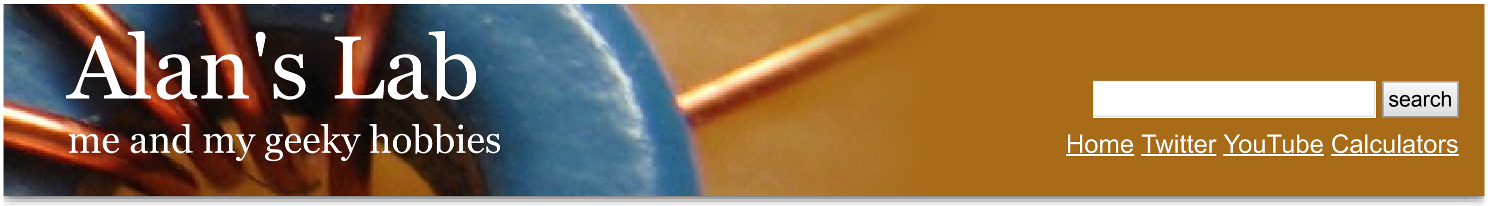
This is my ugly implementation of Jens Dyekjær Madsen's PIC programmer. I omitted the ICSP header as I do not plan to use it. My veroboard embedding of the topology borrows heavily from Paul Scrivens' veroboard version, but mine has a lot more links on the top of the board.

I built it to program OTP 12C50XA chips which are quite cheap (about $2 AU in bulk). I am planning to make a CW beacon controller to bang out "test de vk2zay", maybe with some sequences of vees and a period of long steady carrier for use in my VLF experiments.

Work on a Linux driver is under way as a back burner project. I've become more interested in the ATMEL devices, in particular the 89C2051, which is a flash 8051 compatible. At only 40 cents more for more pins and a faster clock rate, they sound pretty attractive. The lack of an internal clock and reset is a bit of a drawback compared to the tiny 8 pin PICs, at least for the beacon project, but for larger projects they sound like a lot of fun. I've worked with 8051s before, I rather like the instruction set, even if the assembler is in Intel (backwards: opcode dest source ...) order.

The 2051 requires parallel programming, so I will have to Macgyver up some kind of parallel port programmer with a switchable voltage to the reset pin.

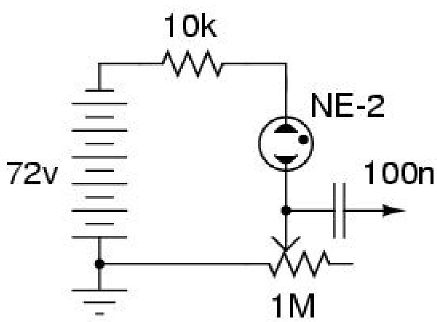
1 comment.



Plasma Diode Detector

2002-12-22

Recently I bought a gross of neon bulbs for various experiments, they are quite cheap in large quantities. While researching neon glow discharges I found a few mentions of their use for microwave demodulation. I've used them for quite a while as sniffers for RF and strong electric fields, even as thyratrons, but I never thought about using their nonlinear diode like properties for demodulation.

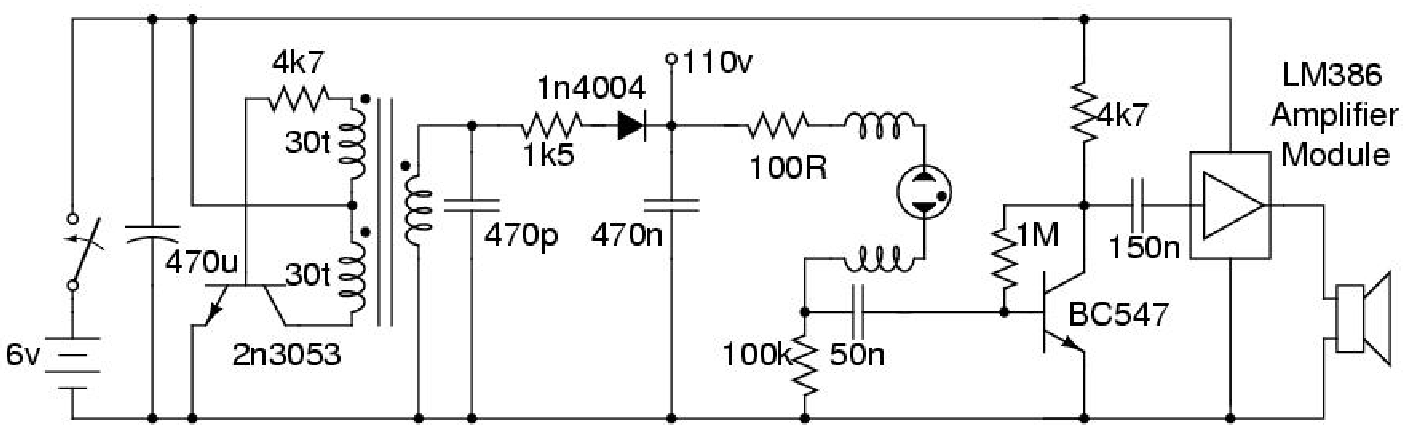


Bias Testing Circuit

While Christmas shopping at a $2-store I saw some cheap and nasty 9v batteries on sale for about $1 each, figuring I could use them for a B+ battery in tube experiments, or some other no-fuss moderate voltage supply, I bought all of them. When this neon experiment came along, I had just the right power supply for experimentation. Using 8 of them and a 1M pot I experimented with biasing a neon bulb and observing the current through it via the voltage across the pot, picked off via a new nano capacitor. It worked very well for such a primitive setup, just a bunch of alligator clips and Blu-Tack holding the prototype together on the bench, the 1kHz AM signal from my RF oscillator was clearly visible on the CRO as a few millivolts above the noise floor while the end of the coax was held near the neon bulb.

Further experimentation with the biasing showed that the current was more important than the voltage in giving the best sensitivity and lowest distortion. While this 1980 Ham Radio article I found in my research suggests altering both parameters I found keeping the voltage above the striking voltage was fine as long as a large series resistance was used to limit the current to the point where a gentle glow was just covering the inner surface of the cathode. Balancing the discharge on the edge of collapse was not needed for my particular bulbs, although there was much variation in strike voltage and best bias current. In practice I found only 3dB or so difference in optimal bias and just giving the bulb 100 volts through 100k.

Building the practical device was a little more complicated, a bunch of 9v batteries is quite heavy and bulky. An inverter had to be built to produce the voltage, and AF amplification had to be provided to drive headphones or a small speaker.



The inverter transformer was wound on a bobbin and ferrite E-core set. The primary windings are 30 turns each, of 0.5mm wire. The secondary winding is 0.2mm wire, wound by trial and error to provide about 110 volts. The primary and secondary layers separated by a layer of PVC tape. The 470p capacitor across it helps improve its efficiency. The 1N4004 was replaced with a Schottky device but little improvement was observed, so the 1N4004 was returned. There is no bleeder resistor across the storage cap, be careful, or add a meg or so resistor across the cap.

The AF amp is a single transistor pre-amp stage, followed by a DSE K5604 LM386 amplifier module. This module is available as a fairly cheap kit (about $5 when I bought 10 of them a few years back) the size and good PCB offers a nice short-cut for building a simple audio amplifier. Here is a picture of the unit without the audio amp module in place. The switch was later replaced with the headphone socket and power supplied externally, I ran out of room inside the box.

Note the RF chokes wound on 1W 10M resistors to isolate the plasma from the supply, preventing the RF from being shunted. The detector seems to work fine from about 5MHz to many, many GHz. As in the Ham Radio article I tried making coupling loops out of flashing Aluminium, they worked quite well for higher frequencies, but for lower frequencies directly coupling the RF to the leads of the neon bulb worked better than capacitive coupling through the glass.

Placing the detector at the focus of a parabolic dish worked well. I could hear the output of a 24GHz motion detector from across the room, chopped with a metal shutter on a small electric motor to give it some AM.

2 comments.

Attachments

title	type	size
bias testing circuit postscript source	application/postscript	10.329 kbytes
detector circuit postscript source	application/postscript	15.439 kbytes

Pulse-Counting FM Broadcast Receiver

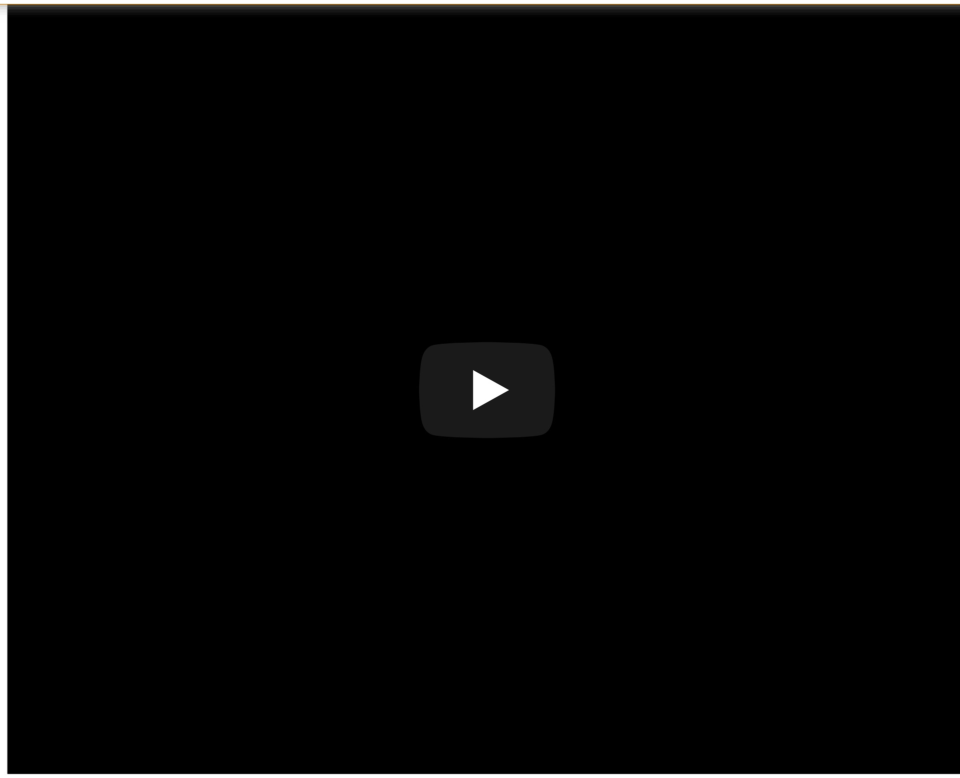
2010-11-14

Months ago when I was working in Cronulla I had plenty of time on the daily rail commute to design a pulse-integration circuit in LT Spice. At one point I threw the result together on a solderless breadboard and tested it with the signal generator - it worked well, but was far from a complete WBFM receiver. I forgot the idea for a while and built the Fremodyne instead. Last weekend I decided to revisit the idea. This radio receiver is the result.

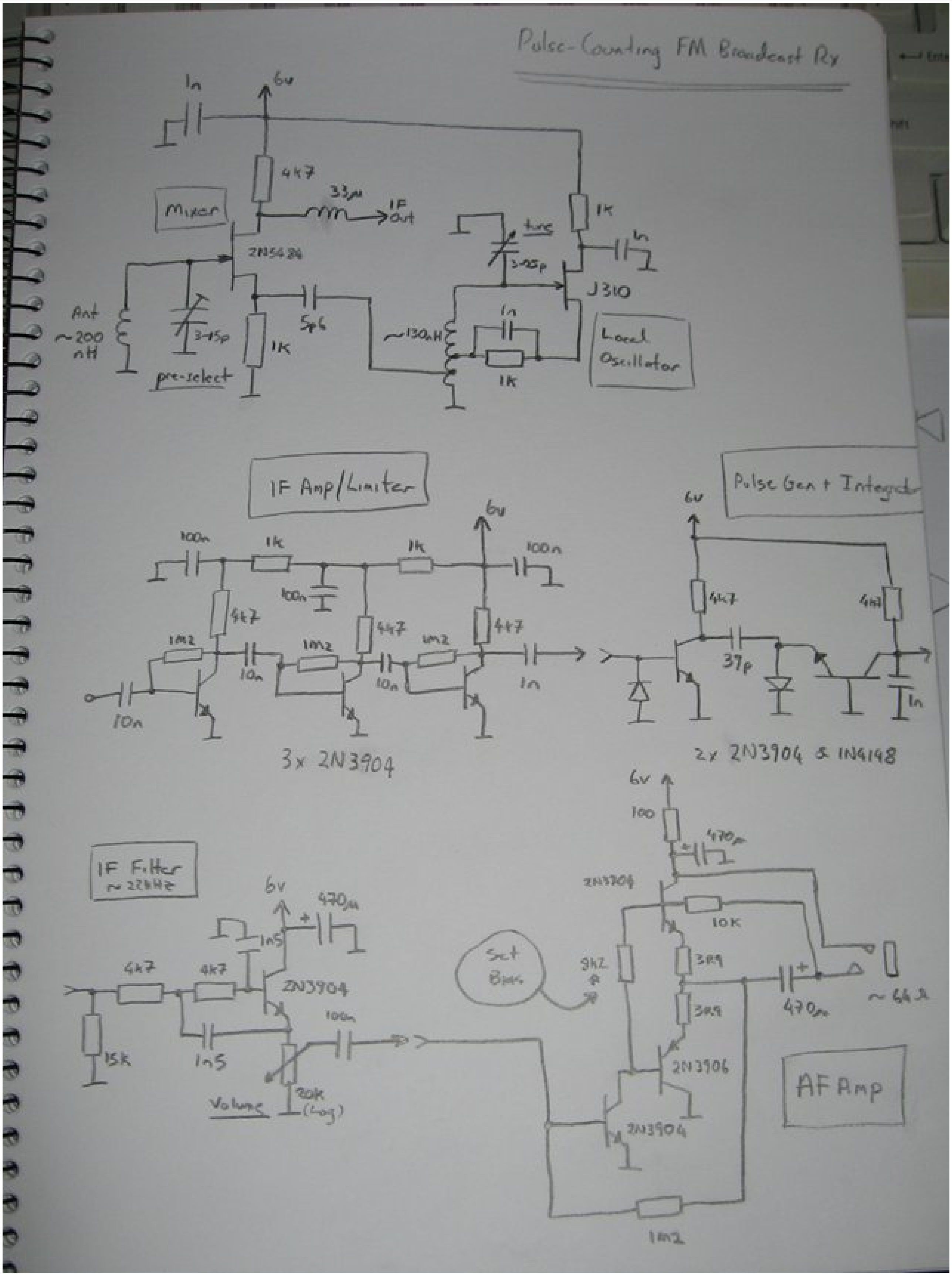
The design isn't fully optimised, the IF in particular is just bench-sweepings, and the audio amplifier isn't going to set any audiophile benchmarks, but for the most part the result is very pleasing to use. The pulse-integration discrimination method is inherently low distortion, high dynamic range, and has a frequency response to DC. Compared to super-regenerative FM receivers of the past this receiver sounds spectacular!

Pulse-Counting?

What is pulse-counting FM detection? Basically you generate a constant-width (narrow) pulse for each cycle of a signal (say at the zero crossing) and integrate the pulses to produce a "DC" voltage directly proportional to the frequency of the signal. This is the familiar "tachometer" circuit used in many places. Changes in frequency produce corresponding changes in the voltage stored in the integrator capacitor - essentially an ideal FM discriminator. We don't care about the amplitude of the signal only its frequency so the IF can be class-C and is



This radio uses a low-IF with a single conversion front-end. FM broadcast uses +/- 75 kHz peak deviation, so the IF needs to be at least 100 kHz or so and have a bandwidth of about 200 kHz. Channel spacing is 200 kHz too, which presents a bit of a problem, but in practice even a roughly designed IF/Limiter will perform fairly well. The FM multiplex signal has energy to at least 53 kHz so if you want to recover it you need to be a bit more careful about the IF system. This radio is not so careful and uses a very brute-force topology.



This simplistic design means there are two "optimal" local oscillator tuning spots per channel (+/- the IF relative to the carrier). In between the LO mixes down and/or aliases the IF into the audible range which is undesirable (sounds horrible). Ideally the IF amplifier only amplifies signals above "baseband" up to the peak IF frequency and the detector is followed by a filter that rejects the IF. This radio does the later with a simple Sallen Key filter, but the former isn't really implemented beyond the inter-stage coupling of the IF stages which roll off its gain towards lower frequencies. None the less the result is quite acceptable at the expense of a poorer signal to

noise ratio at baseband where a bit of "out of band IF" leaks through the detector on weak signals. Once in full limiting it isn't really a problem as only intermodulation can mix IF energy down into baseband.

RF Front-End

The front-end is a simplistic single-JFET mixer with a tuned-loop antenna on the gate. A Hartley JFET oscillator implements the LO, and injects into the low-Z source of the mixer JFET from a tap on the LO tank quite close to the cold end. The IF is extracted from the drain of the mixer. A choke rejects the higher frequency bits of the mess at the drain, but the IF amplifier does the bulk of the band-limiting - an area that probably needs improvement. The front-end is not particularly sensitive, but I live in a high-signal area so this is of little consequence. The pre-selection tunes sharply which is actually a bit annoying usability wise. Also severely detuned the pre-selector lets you tune the mixer to powerful out-of-band signals, this clobbers the signal of interest at the IF. In a better design the pre-selector would be track-tuned with the LO.

The IF Limiter and Pulse Integrator

The IF limiter is just three cascaded "minimal" common-emitter BJT amplifiers. It is works well enough, but I am not very happy with the design. The pulse-generator was originally designed to be biased slightly on, but I encountered instability problems doing so. It is now "auto-threshold biasing" class-C which decreases the sensitivity to non-limiting IF signals but it behaves... The preceding IF amplifier is largely to blame. In the absence of an input signal it can oscillate. This is a hack. The topology of the pulse-generator may look a little weird with the grounded base, but it is easy to understand if you simulate it in LT Spice - basically the emitter gets pulled below ground by the 39 pF cap on the edge of the previous stage's collector signal. This produces a very well defined narrow spike of collector conduction, pulling down the collector voltage proportional to the frequency of the IF signal.

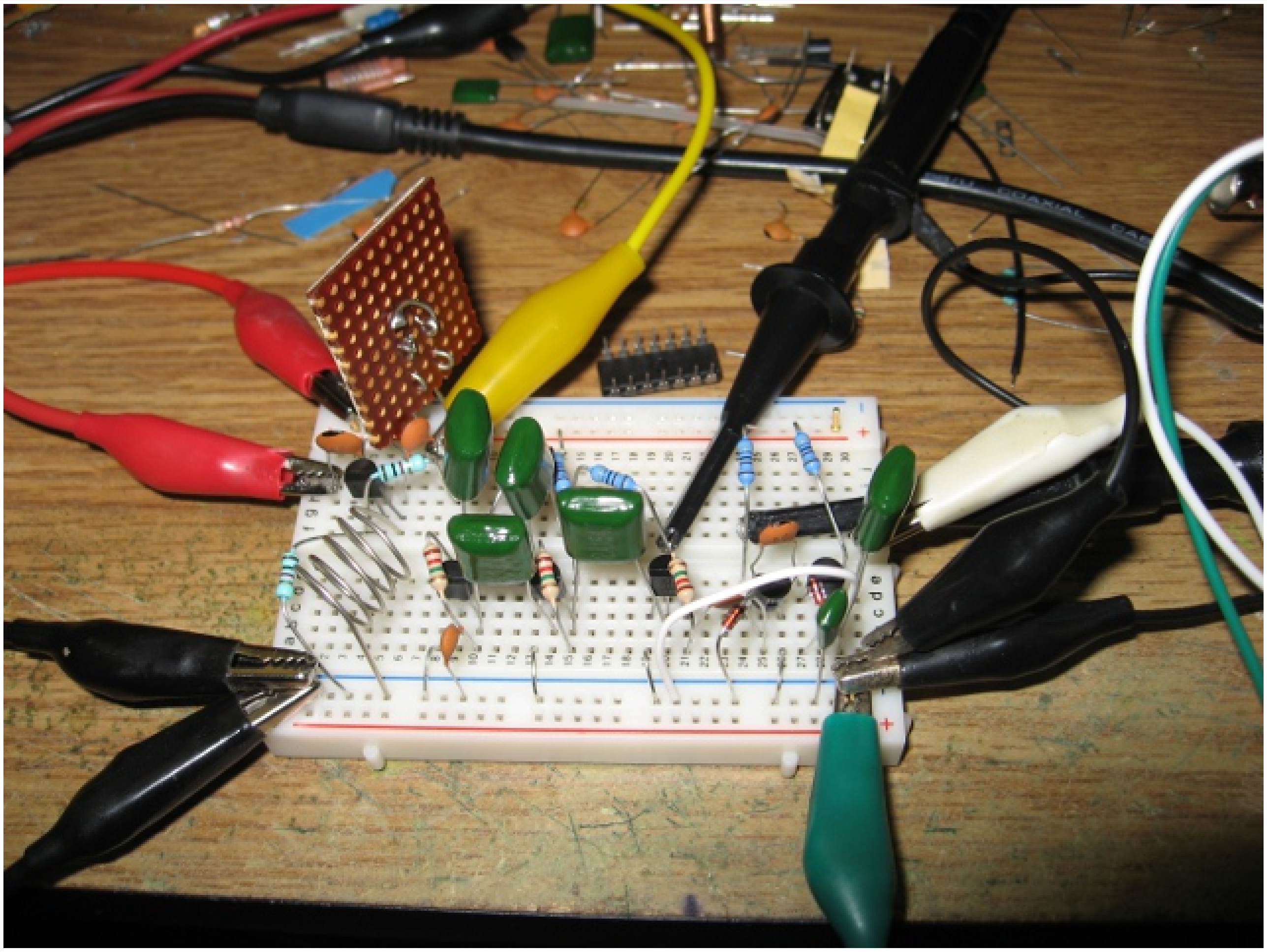
The Audio Bits

I cheated to save a capacitor (and improve the LF response) by using the de-emphasis RC network to bias the Sallen Key emitter follower to near mid-rail on the emitter. The Sallen Key filter has a Q of only 0.5 and a corner of around 22 kHz - it works well enough to keep RF out of the following stages. The emitter resistor of the filter transistor just happens to be the volume control pot too...

The audio power amplifier should probably have been an IC, but I had used transistors for everything else, so what the heck! The result is very conventional complementary output stage with bias boot-strapping to prevent +ve going distortion (if the 10 k resistor just went to V+ instead of the output the bias headroom would eventually run out). The 8k2 resistor selects the quiescent current and minimises cross-over distortion. The 3R9 resistors stabilise the operating point with temperature variations. The frequency response of the output stage runs into LF. Attempts to shape it just coloured the audio too much, its current response could be considered a feature. The lower frequency corner is quite good - excellent in fact, fine for headphones. Output power is more than adequate, ear splitting in fact. The circuit can drive lower impedances, but prefers the 64R of headphones. Because of the bias boot-strapping it will not perform well into higher-Z loads and requires DC continuity.

Notes

The radio was first built on a solderless breadboard as just the mixer, IF and pulse integrator, using my signal generator as the LO. In this form is was actually more forgiving than once built on a PCB. Most of the development time was spent keeping it stable on the PCB through addition of RF-hygiene. The filtering of the IF rail supply could be better, 100 nF is probably too small. In hind-site, the lack of reasonable filtering down to audio frequencies at the mixer drain is probably a major problem...



The receiver sounds good enough to actually use for listening to ABC Classic FM (92.9 MHz here in Sydney). The response is quite flat and uncoloured despite little attempt being made to implement de-emphasis properly. The LF response is excellent. The signal to noise ratio could be improved a bit, you don't notice this on most channels, only in the quiet passages of classical content can you notice the noise floor. On a spectrogram you can see the 19 kHz pilot signal of the stereo MPX (it is about 30 dB down once it makes it though the filtering), with a bit of effort it might be possible to build a stereo version...

Selectivity is a compromise of course, but the pre-selector helps. Often one of the sides is better than the other as it has a "quieter" adjacent band. Dual conversion would help eliminate the image response along with ceramic filters.

The loop antenna makes the receiver a bit fragile for my liking. A solenoidal inductor could replace it at some loss of capture aperture (see breadboard version photo - worked fine). The loop antenna interacts with the headphone lead a bit (the headphones act as a parasitic antenna too and not always for better signal as the phase relationship between them is uncontrolled). One might wish to add chokes to the headphone line and tap off the RF it collects for injection into the mixer instead of the using the loop antenna.

The receiver pulls about 10 mA and runs from four AA cells.

14 comments.

Attachments

title	type	size
Large Version of the Circuit Diagram	image/jpeg	339.579 kbytes

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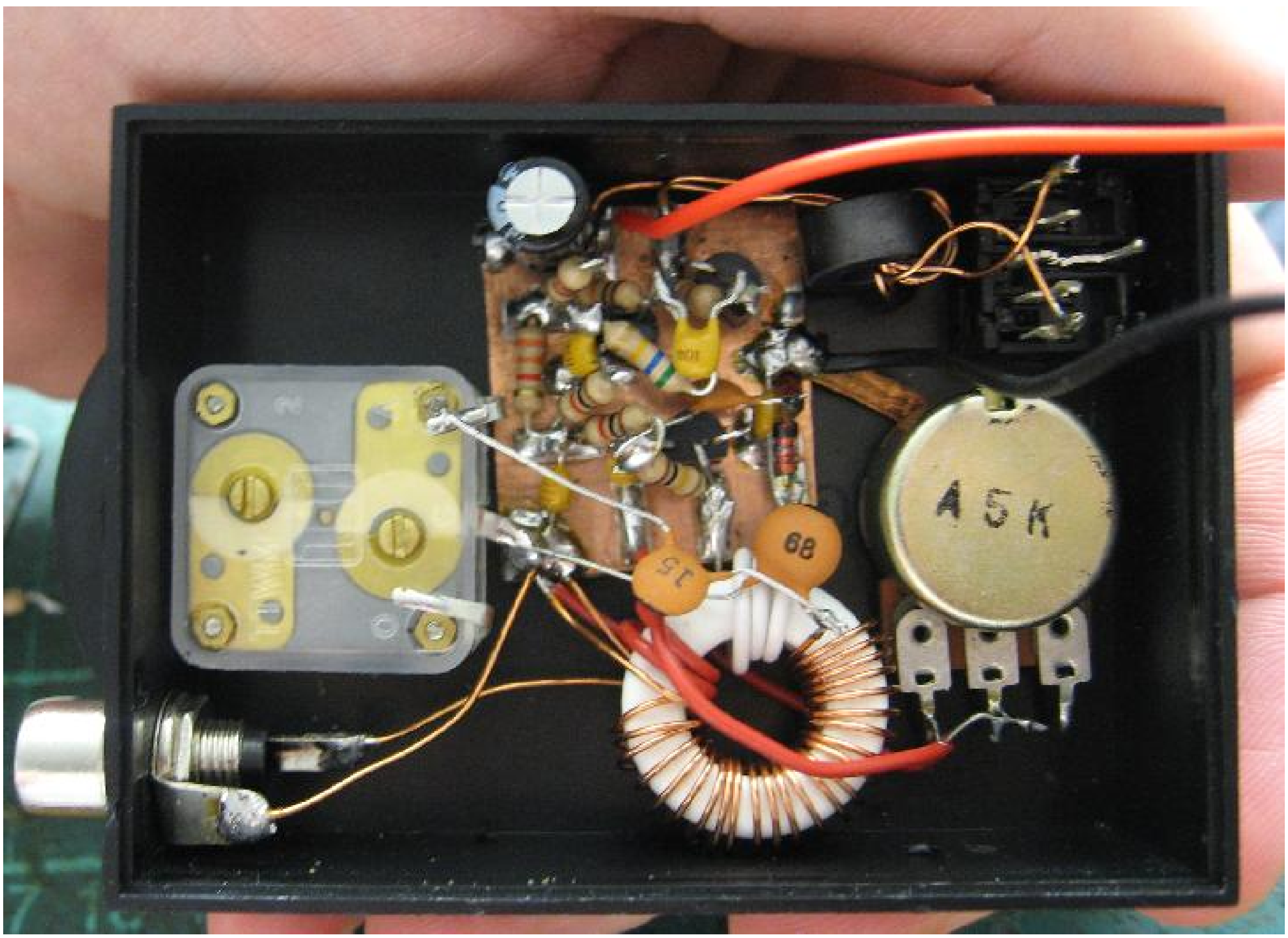
Receiver Boxed Up

2007-12-18

I finally got around to putting the PA2OHH-style Reflexing-Regenerative Receiver circuit into a more permanent form. The tuning was arranged to cover 31 metres, spread nicely across the dial. It is no longer touchy to use and tunes slowly through the band. There is a slight body capacitance effect on the spot on the box nearest the coil, but it is hardly noticable unless you are using the receiver oscillating. For using a plastic box (a cheap Jaycar potting box) it is surprisingly stable. I chose this box so as to keep the guts accessible for tinkering and show-and-tell purposes.

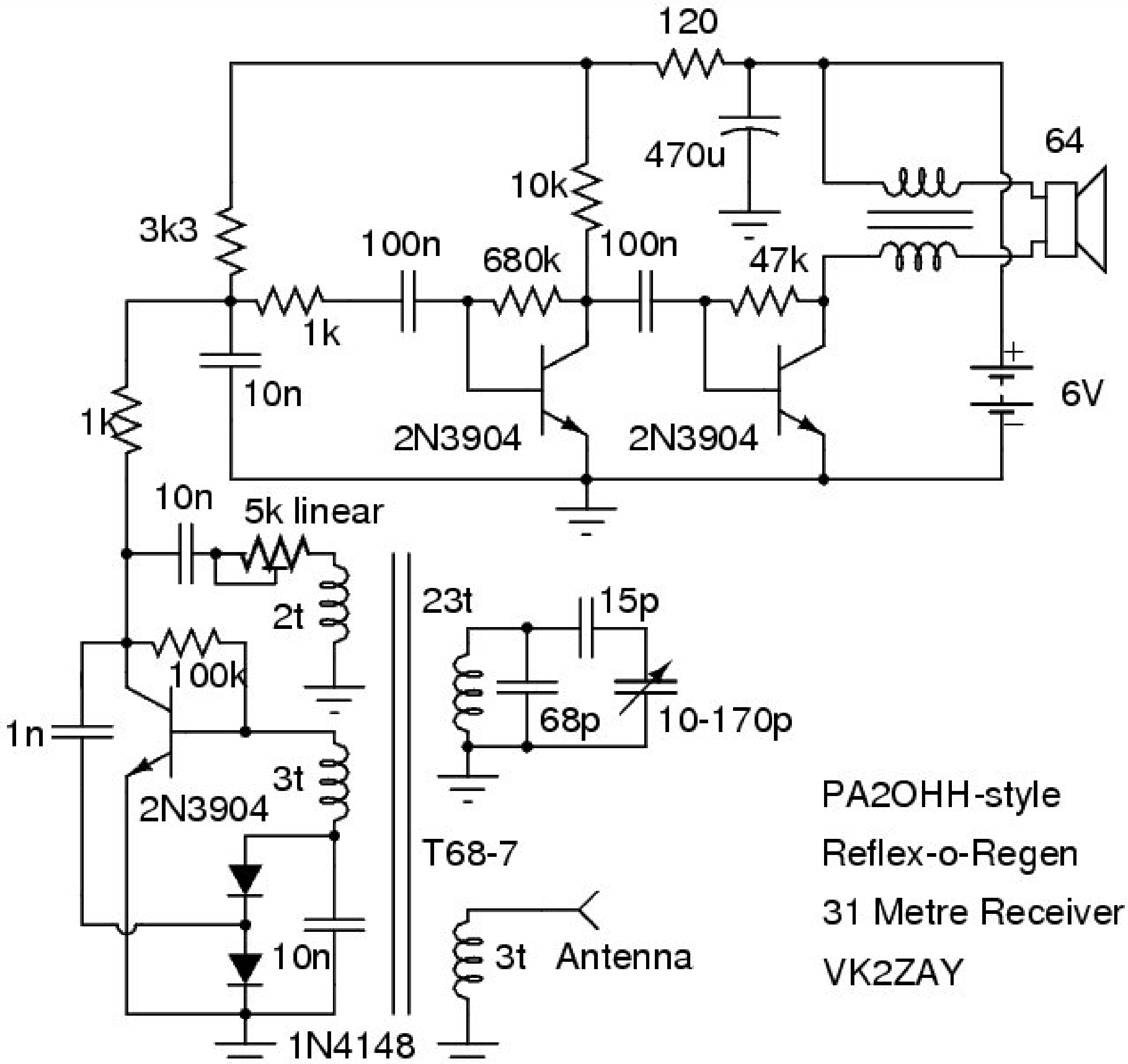
A very simple audio amplifier was built into the radio to make it self-contained, driving standard 32 Ohm headphones in series. Its fidelity isn't wonderful, but its a reasonable match for the quality of the detector. There is a common-mode choke in the headphone lead to prevent any stray RF getting into the audio amplifier (which isn't especially well designed to reject RFI). The choke was added after experiencing some minor problems with FM and TV stations breaking into the AF-side of the radio.



The dial has not been calibrated yet, and probably won't be. There is no front-end at all, the antenna is directly coupled to the resonator, so this is really only a toy radio, but it is quite usable for shortwave listening. I don't think it is too bad for 3 transistors and only a few mA of draw. The huge knob is all I had which wasn't for fluted shafts, but its large size is useful for smooth tuning, so I may keep it that way if I'm not going to calibrate the dial.

XHTML | CSS | CSS toggle

The circuit diagram.



8 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	18.217 kbytes

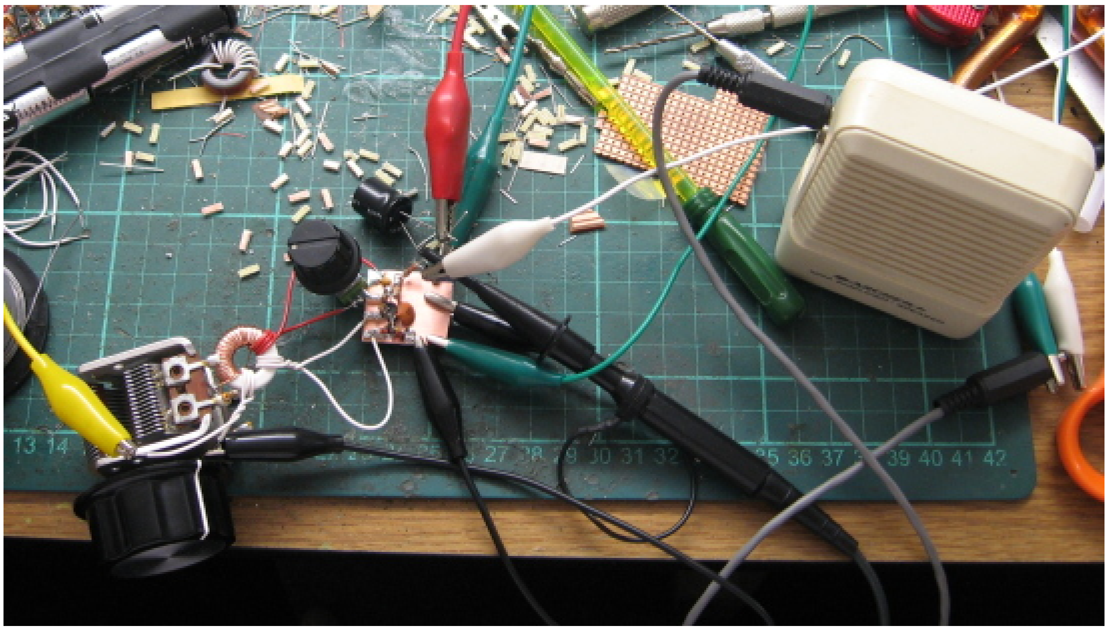
Parent article: Regenenerative-Reflexive Receiver.

Regenenerative-Reflexive Receiver

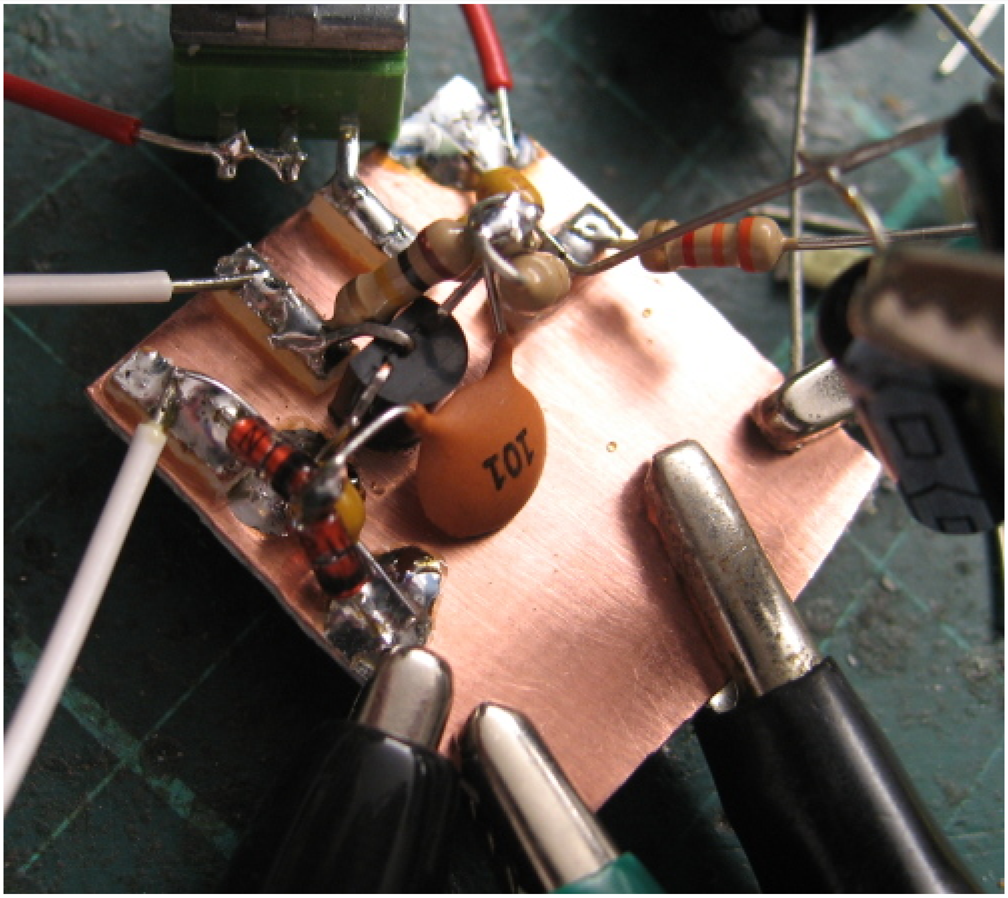
2007-11-04

I first saw this detector topology on PA2OHH's website, and then again saw that PY2OHH had a go at it as well. I had to give it a try, it is obviously regenerative, but also appeared to be partially reflexive.

The circuit is simple and was thrown together in only a few minutes on a small piece of PCB. The lash-up included just the detector, using a T68-7 core for the coil and large tuning capacitor. The detected audio was delivered to my old Archer amplified speaker to quickly assess the circuit.



It works very well. The -ve feedback from the collector to the base bias helps control its break into oscillation. Initially I used 100 pF, but I increased this to 1 nF for smoother operation. This also enhances its reflexive properties, giving it quite good audio gain with only one transistor.



There is some distortion inherent in the detector, but its simplicity and stability is a big advantage. It took only minutes to get a working receiver with it, and easily heard the stronger shortwave stations with only two alligator clip leads for the antenna.

Here are some videos of the prototype receiver in operation (excuse the enormous mess my bench is currently in):

- Some Jazz on VOA (2 MiB)
- Tuning Around (4 MiB)

As there is no bandspread capacitance or reduction drive in this initial lash-up; the receiver is very touchy to tune. The full sweep of the cap tunes from about 3.9 MHz to over 18 MHz, far too much bandspread for practical use. This is easily fixed in a more permanent version of the receiver however.

3 comments.

Updates

2007-12-18: Receiver Boxed Up
: I put the regen-o-reflexive receiver on 31 metres and put it in a box.

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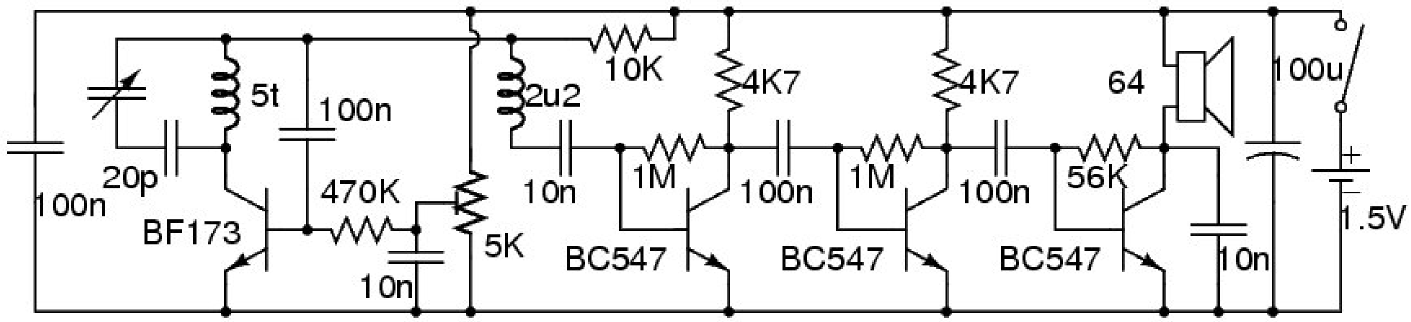
Home Twitter YouTube Calculators

Regenerative FM Broadcast Receiver

2006-08-13

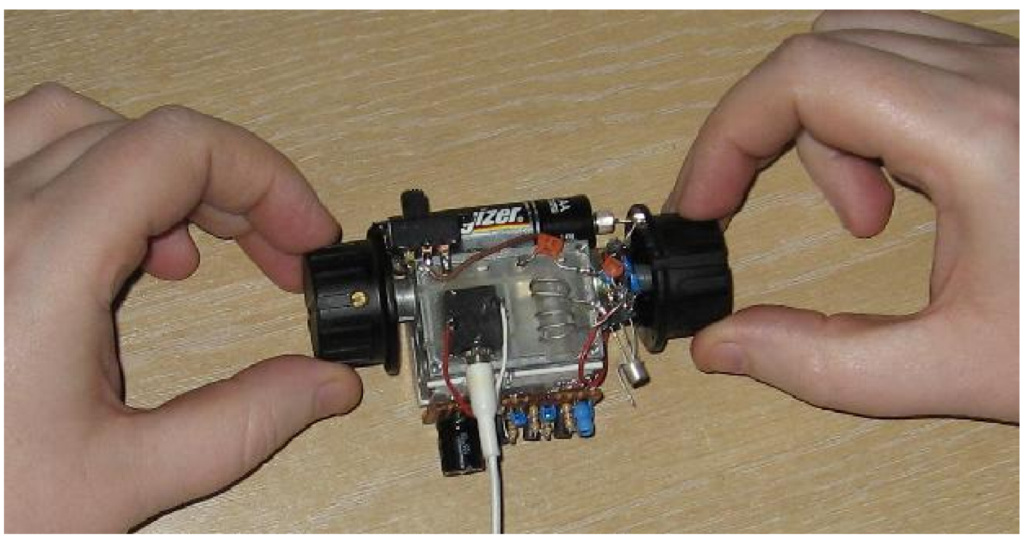
This radio comes from Everyday Practical Electronics magazine, January 2006, in the Ingenuity Unlimited (Readers Circuits) section. Francis Hall, from Meinerzhagen, Germany calls it his "Euro Set". I made only minor changes to the circuit, the diagram below is as I built it, see the article for as Francis specified it.



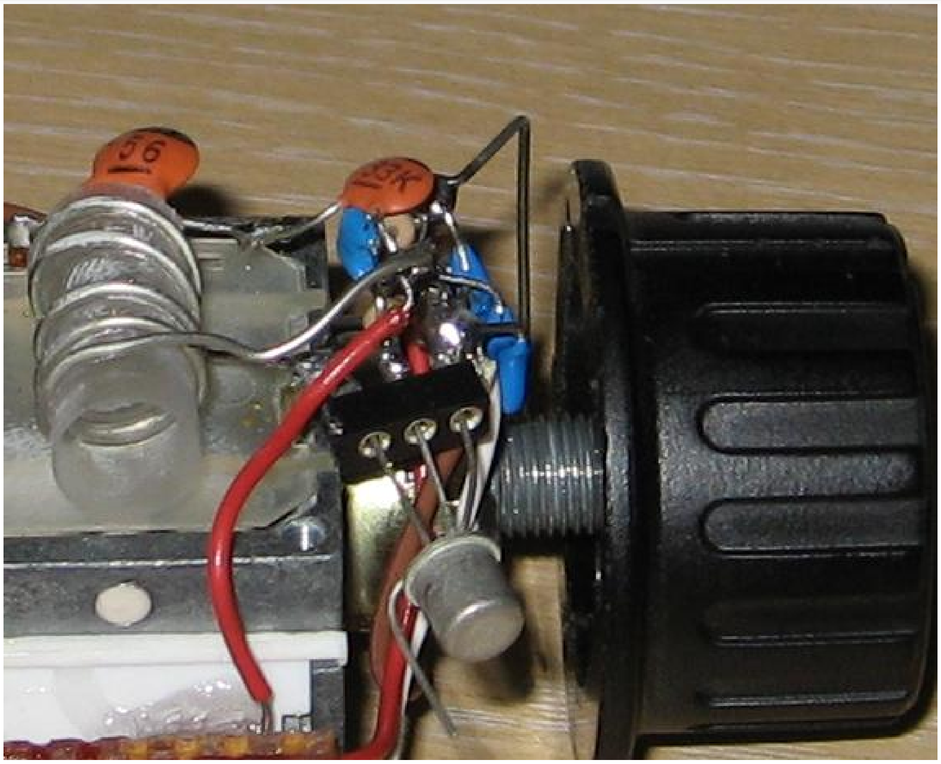
I must admit, at first I was sceptical looking at the circuit diagram, a single 1.5 V cell supply? But after a quick check of the audio stage bias with my calculator I saw that Mr Hall had designed it well, so I dug out the solderless breadboard and made up the audio strip. It "blurt" tested OK, and was surprisingly quiet and well-behaved (I used BC548B devices).

The front-end was more problematic, it was obvious that a real RF transistor would be required. The article specified a BF199, but I had none in stock, so I built a point-to-point hack of the circuit with a piece of IC socket to allow experimentation with whatever transistors I had in the junk box. Initial experiments were frustrating, I began to believe it would never oscillate, BC54x's definately don't cut it, neither did a PN3563, or a whole stack of 2SC's I tried. Eventually I found an ancient BF173, on plugging that in I saw a new peak on the spectrum analyzer - it was oscillating at last!

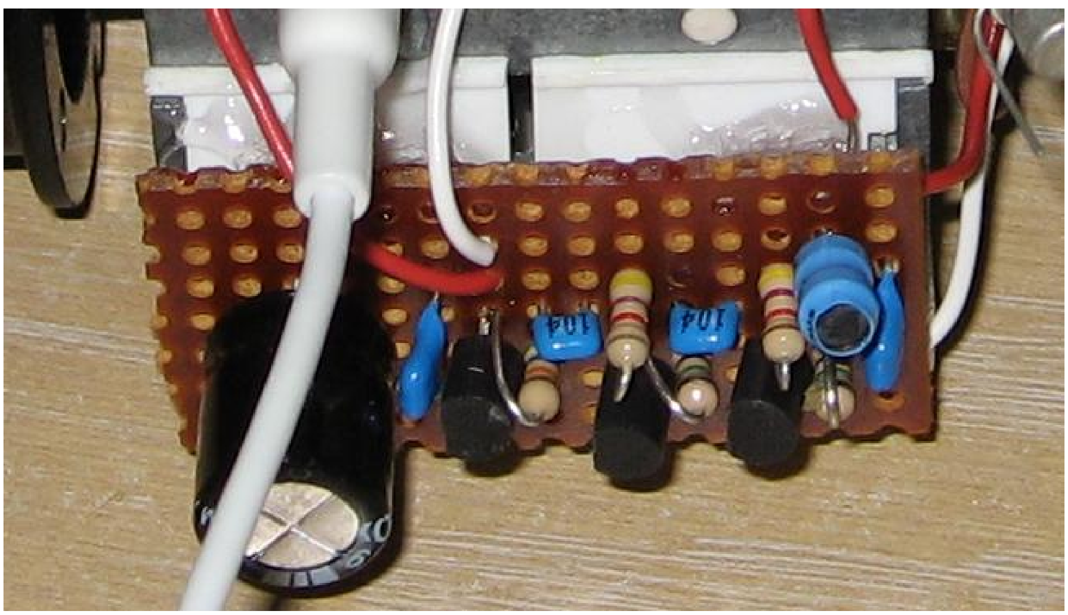
Now that I had a transistor that would oscillate, I rebuilt the front-end around a large tuning gang with an internal 2:1 reduction drive. (I got this unit from KW Tubes on eBay several years ago.). I substituted a 5K pot for the 10K one specified (all I had), and superglued it to the end of the tuning gang, giving me a device with a knob on each end. This physical arrangement is actually quite nice to use.



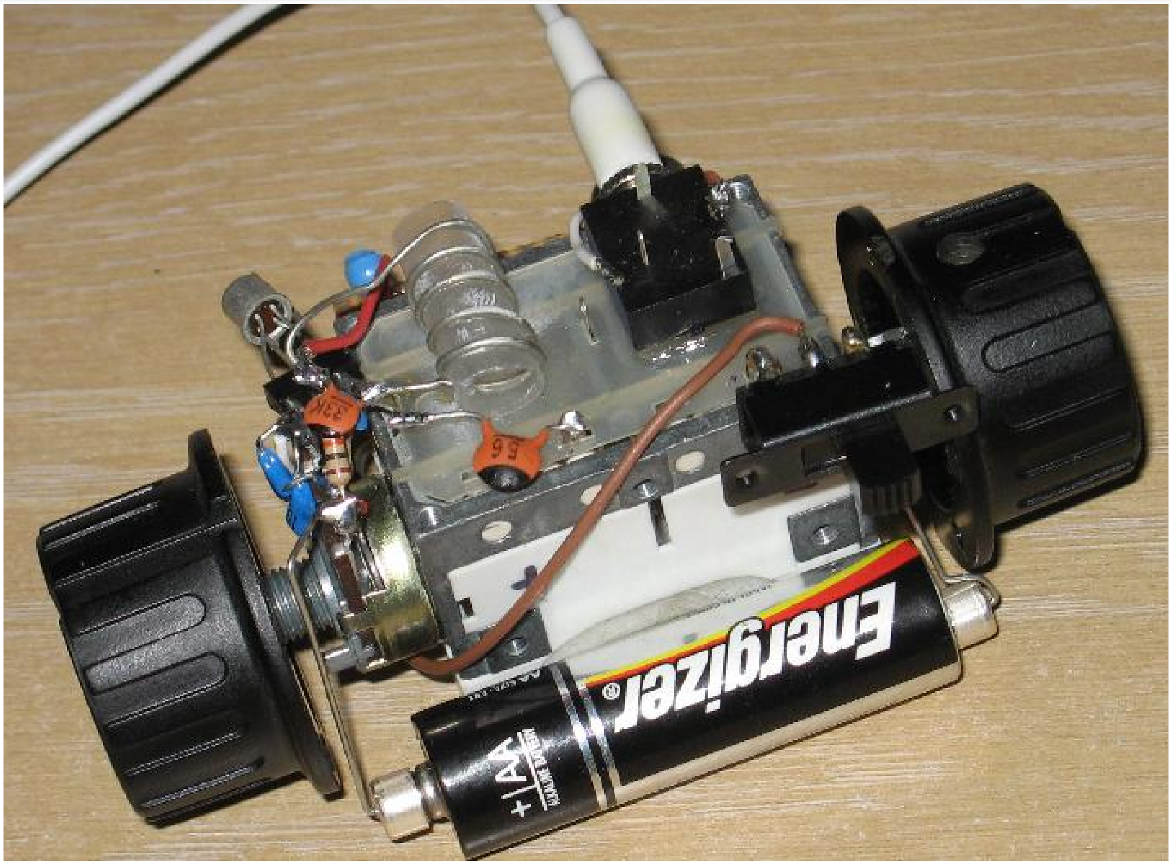
I retained the transistor socket, so other devices could be tried in the future. One thing became obvious during experimentation, it *requires* a large L:C ratio. Too much capacitance and it will not oscillate at 1.5V. The biggest challenge seems to be to get it oscillating, then you can adjust the components to the frequency band of interest. My frequency determining components, the coil, tuning gang, and series caps and quite different from the article - yours probably will be too. I used 5 turns of tinned 0.71 mm wire on a soda straw for the coil. I am unsure of the capacitance on the gang, I didn't measure it. The bandspread cap is a 56 pF in series with a 33 pF = near 20.7 pF. Mine tunes about 85 MHz to 122 MHz. I could achieve better bandspread, but with the reduction drive the radio is fairly easy to use as-is. Covering part of the airband is a nice feature too.



The audio amp was rebuilt on a piece of punch-board, this time using NOS Philips BC547s which aren't quite as good as the devices used in the breadboard test, but which worked fine. Some 5-minute epoxy was used to glue the board and headphone socket to the frame of the tuning gang. A slide switch was added as an "on" switch, and a pair of magnetic battery connectors (Jaycar) were used to make connection to the AA cell powering the device.



The completed device pulls about 2.5 mA, giving it a very long battery life. The regenerative stage and the first two audio pre-amps draw 450 uA.



The Good

The radio is an excellent performer. It easily picks up all the local channels with more than enough volume. With the regeneration turned up it is narrow enough to distort the received signal purely because its bandwidth is too narrow for the signal's deviation.

Its audio quality is surprisingly good. Unlike the super-regenerative receivers I've built in the past there is no quench to mix the stereo sub-carrier and pilot into the baseband. It can also have an extremely high-Q, unlike the super-regenerative receivers which have a minimum bandwith of four times the quench. It is perhaps slightly less sensitive, but much, much nicer to use; far easier to tune for best audio quality.

To tune, you may use the RF stage gently oscillating to locate the station of interest. Tuning across a station will sound like listening to FM on a SSB receiver as most of the signal's energy will be outside the detector slope. Once you've got a channel near-by, you back-off the regeneration until it stops oscillating and the Q is at an optimal point, then shift the frequency to put the slope at the best position for low distortion. This requires some dexterity, manipulating the tune and regeneration controls at the same time to place the signal in the bandpass and adjust its width for an undistorted audio output. It takes more words to describe than actually do, you will quickly become proficient.

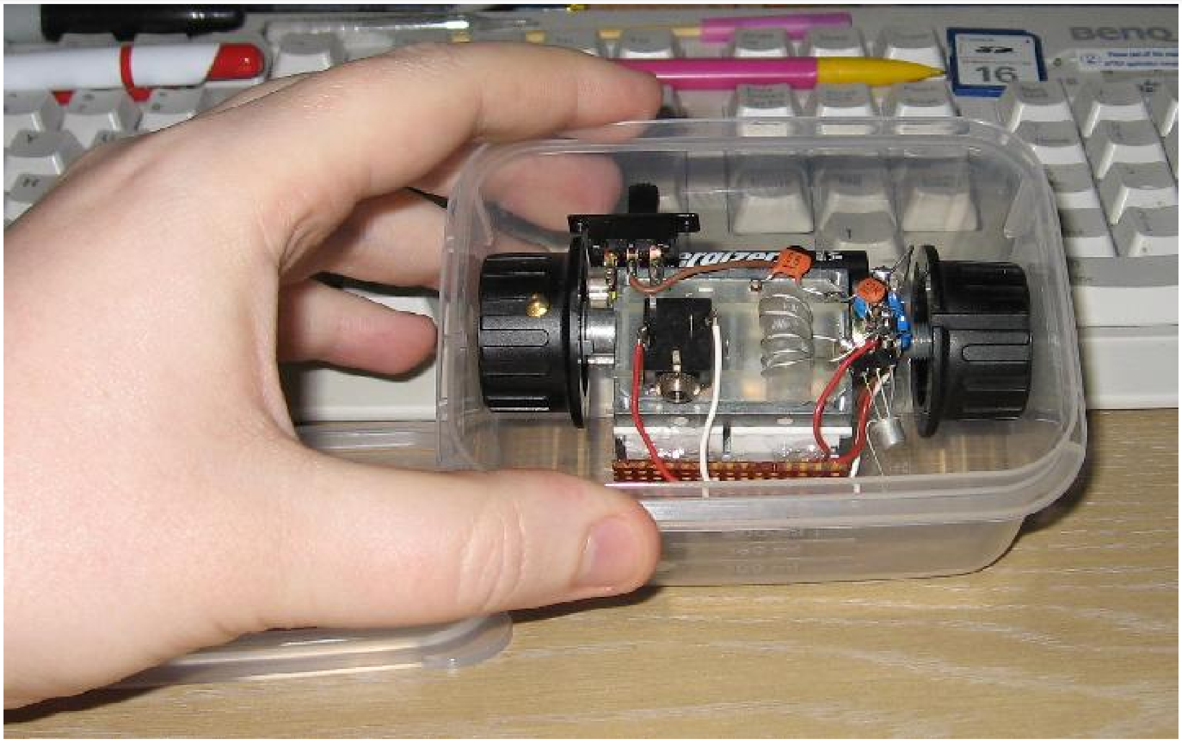
The Bad

Because of the regenerative stage topology, neither side of the tuning cap can be referenced to ground. This means the entire bulk of the receiver is RF hot, which makes it suffer badly from hand-capacitance effects. The regeneration control spindle is coupled to this capacitively (via its case) because I glued it directly to the gang frame - a physical design problem, not a limitation of the circuit as the former is, but annoying none the less. I would like to redesign the regenerative stage to use a common-base oscillator which should make the radio much more stable and pleasent to use.

There is no volume control. With strong signals the RF stage can overdrive the audio stage. At the very least this is painfully loud, but it also pushes the relatively simple amps into their +ve-going distortion and even into full clipping on very strong local signals. (The local ABC Classic FM - 92.9 MHz is a good example, it is a gigantic signal at my QTH and simply can't be tuned in properly at any regeneration level). Turning down the regeneration as a volume control is very non-optimal, it rapidly reduces the Q of the tuned circuit, widening the bandwidth and destroying the selectivity, however this does work for powerful stations in otherwise relatively quiet parts of the band (2WS FM - 101.7 MHz for example).

The Ugly

This radio is quite possibly the ugliest thing I've ever built. It is fairly small, and fits in a Decor 250 ml plastic tub for transport, but its still an ugly hack.



Usage Experence

The lack of AGC means mobile use can be almost impossible. Unlike lower wave bands where the longer wave lengths mean multipathing isn't a huge issue, at VHF multipath related fading is severe. Over water or in the city the fades can be so extreme and rapid it is very difficult to tune the radio, or listen to the program.

Stationary the device is quite pleasant to use, despite the body-capacitance issue. I've been considering lowering the gain of the 1st audio stage or putting in a volume pot, the radio is significantly more sensitive than is required at times, and often keeping it sufficiently selective in the crowded 50 kW+ upper-end of the FM band means the audio is simply too loud or distorted.

The radio suffers mildly from being unshielded. Some interference from mobile phones in close proximity is experienced, but putting your finger on the 1st audio stage biasing resistors shunts most of it. The problem is quite minor however, no where near as severe as with the recent MW Receiver with gets hammered by any phone within 20 metres and TV transmitters in Sydney Harbour.

Future Ideas

My next attempt at a similar radio will probably be a hybrid including a regenerative stage at a fixed IF in the HF region, with a front-end converter based on a varicap tuned VFO feeding a simple cascode mixer. I'll carefully design an 80-115 MHz filter and an LNA to feed it from signals taken from the headphone lead and build the entire circuit inside a shielded box to avoid mobile phone noise. I may be able to implement an AGC at the LNA stage, or a diode attenuator in the front-end to control the total system gain, however this will degrade the noise figure a bit - on the FM broadcast band this shouldn't be a huge issue as the signals are generally quite strong in the metro area where I'll be mostly using the unit. That said, a non-linear element in the front-end might produce intermod issues from the same very powerful signals in-band, so varying the gain of the LNA might be the better approach.

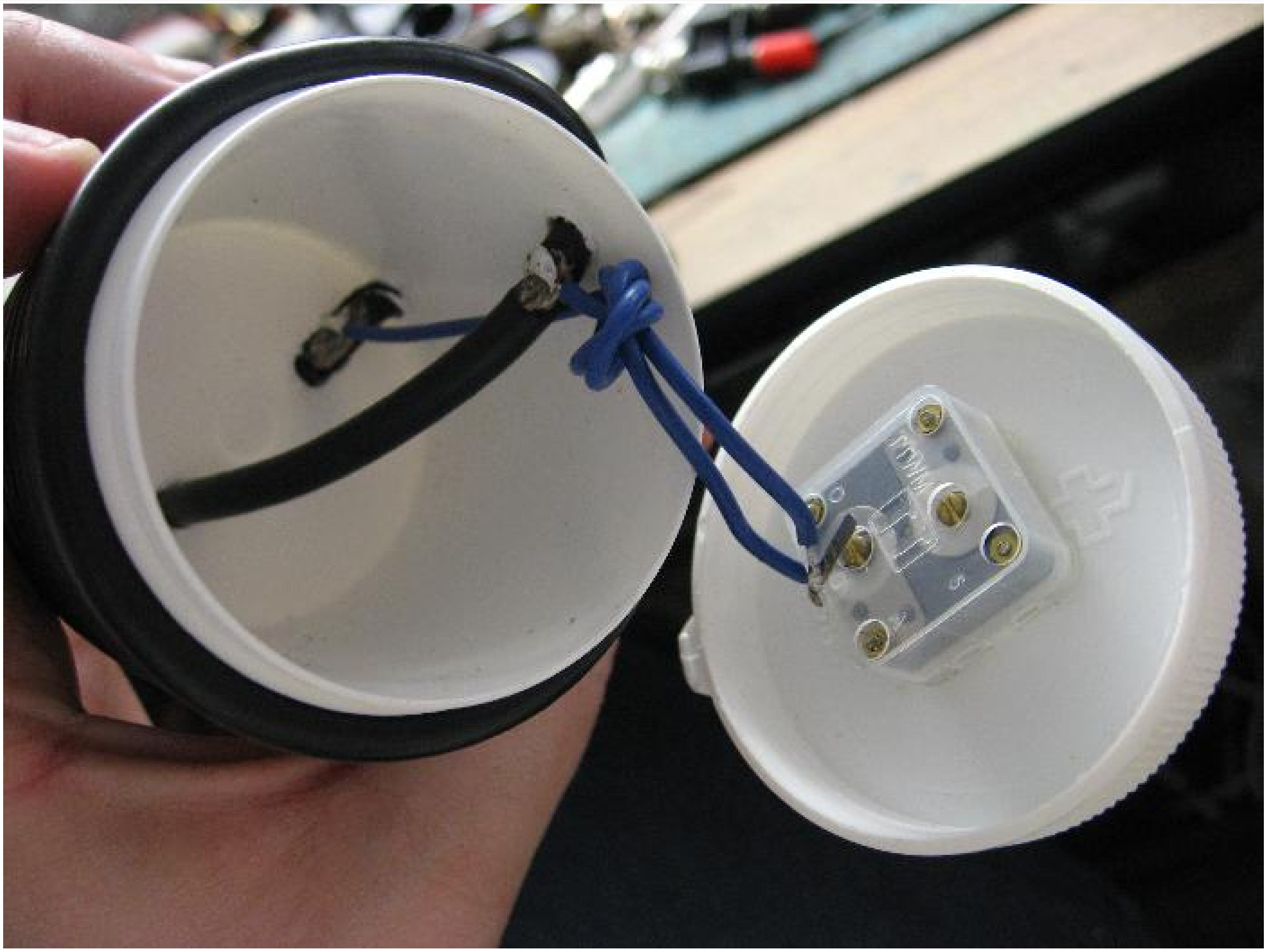
10 comments.

Resonant Coaxial Feedline Choke

2008-09-28

This is a tool I've been meaning to make for a while. For HF antenna experiments it is often useful to be able to selectively choke the feedline of common-mode currents. While you can use a ferrite bead choke or some arbitrary coil of coax to provide a bit of impedance, a resonant choke is tunable so you can make measurements with it still inline but detuned and then quickly tune it up for comparison.

The coil form is simply a plastic pill bottle about 50 mm in diameter. Onto this 9 turns of RG-58 coax are wound giving an inductance of about 3.5 uH. The coax passes out the bottom of the bottle and is terminated in BNCs. Inside the bottle the braid of the coax is exposed at each end of the coil and connected across a polyvaricon installed in the lid of the bottle. Liquid electrical tape (like RTV) is used to seal up the coax again and bottle penetrations.



The lid is calibrated in MHz, performed by dipping the coil or tuning it to resonance near the output of my signal generator while monitoring the voltage across the BNC plugs on the CRO with a suitably small cap in series. The device tunes 5.7 MHz to beyond 16 MHz using the full 210 pF maximum capacitance of the polyvaricon's combined gangs. The distributed capacitance of the coil plus internal wiring capacitance is around 12 pF limiting operation to around 20 MHz tops.

Usage

It covers 20, 30 and 40 metres (it was designed for 40 metres in particular), and 17 metres too but the tuning gets fiddly up there. The general idea is scalable to any frequency. Tune-up is simple, place a clamp-on RF ammeter over the coax and tune for a dip in current. Alternatively you may pre-tune with a dipper, but it is easier to tune in-place where the extra capacitances of the feedline are attached. Pre-tuning will generally need to be tweaked up (less capacitance) because of the extra capacitance between the feedline ends.

It is fairly common practice to use self-resonance without additional lumped capacitance at VHF and UHF to choke feedlines, but it seems few people actually try for a resonant breaker, just adding "a few turns" in the feedline. With a dipper it is easy to fiddle with a roughly dimensioned coil of coax until you get resonance where you want it, then tighten zip-ties to hold the coil in place. Q is generally low at higher frequencies using the coil's self-resonance so tuning is not too touchy, but it must be done with care to get the best results.

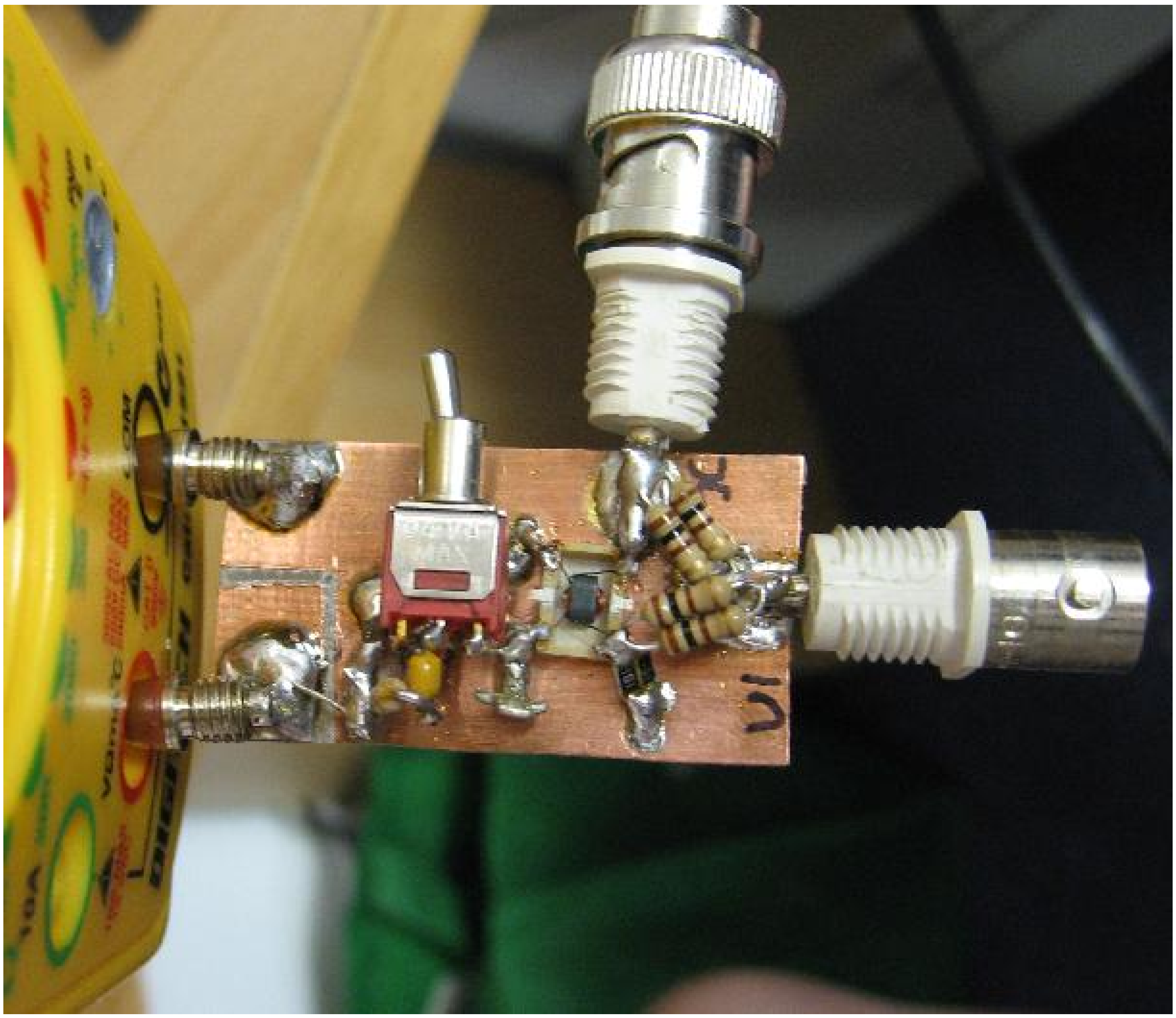
The resonating of the coax braid like this DOES NOT effect currents flowing inside the coax. (I confirmed this experimentally to the limits of my return loss bridge.) Only currents trying to flow on the outside of the coax experience the impedance of the tank so formed. The Q of the tank is not especially good, the coil being close-wound of coax braid, but it offers at least several tens of kilo-Ohms to braid currents at resonance and is broad enough to not need much retuning in narrow bands. It is possible to construct a similar device for balanced lines, using isolated dual capacitors across bifilar mutually wound inductors fed by the feedline.

2 comments.

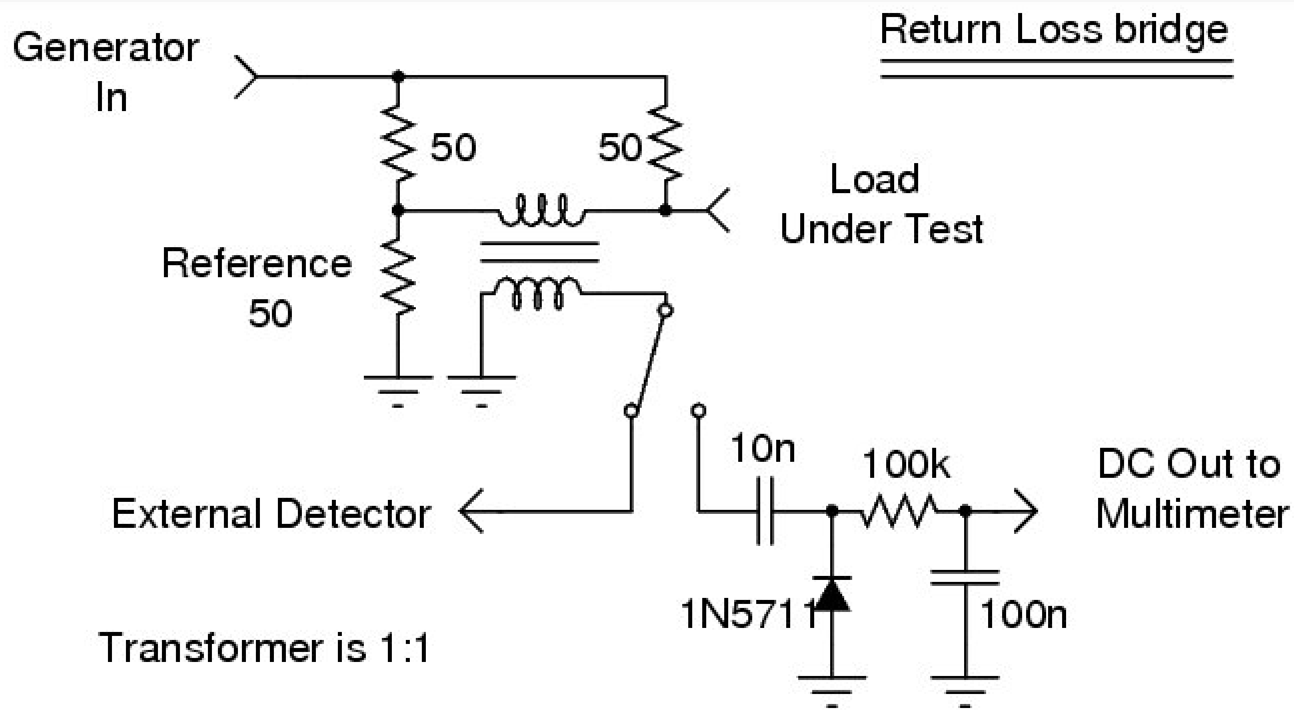
Return Loss Bridge

2008-08-02

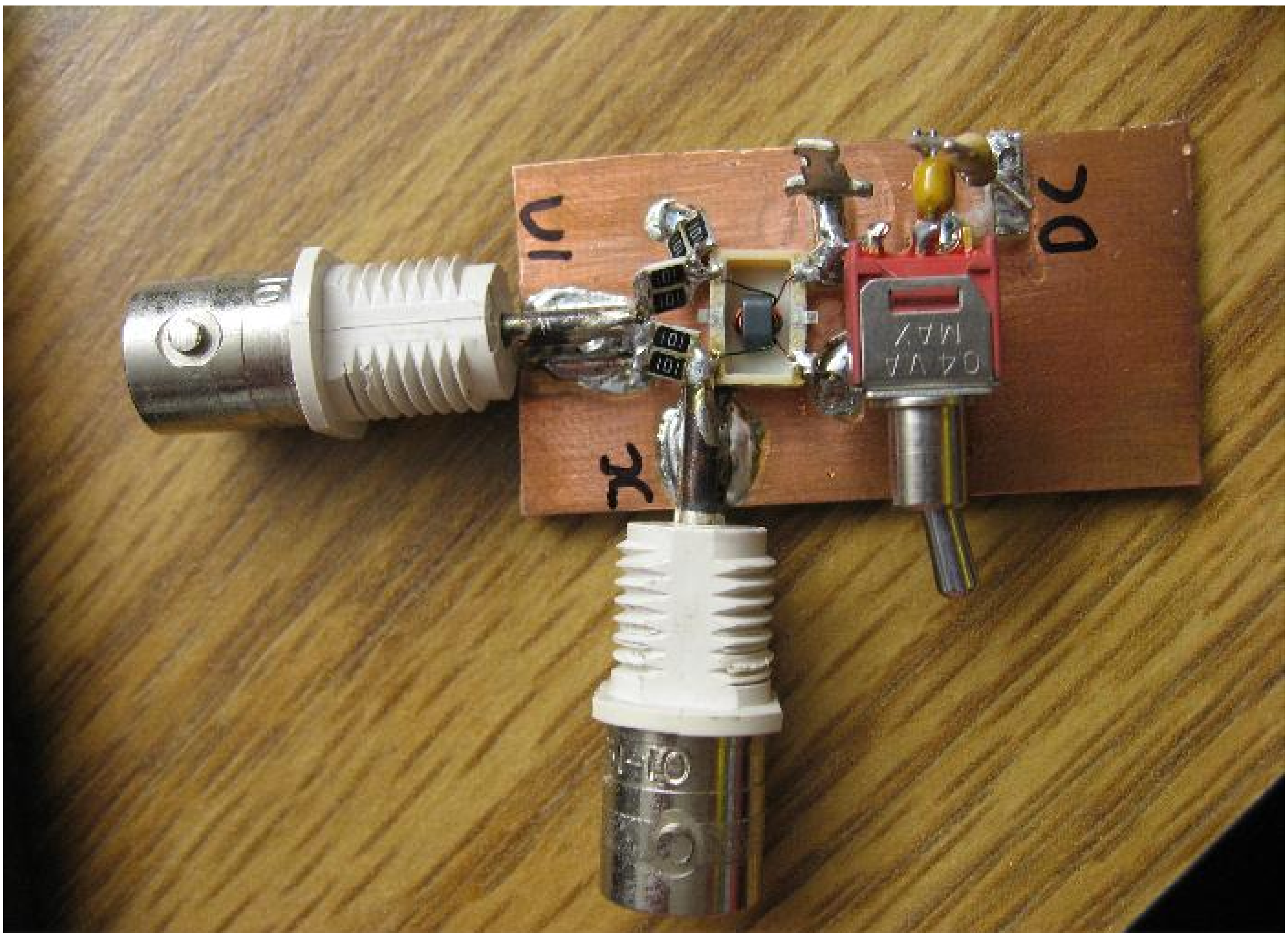
I've built many return loss bridges over the years, this is but another. I've actually been using it for a while, but only just today got around to adding banana plugs for easy attachment to a multimeter and of course writing it up on the website. Unlike the VHF Impedance Bridge, output to a multimeter allows fairly precise measurement of return loss. The meter scale of the older bridge is better for tuning for best return-loss, or you might use a VOM instead of a digital meter with this bridge. The older meter still allows estimation of the reflection coefficient and comparisons between the instruments suggests the previous readings were quite valid.



The circuit is extremely simple and can be thrown together in a few minutes. I don't really use the external detector output much, it would be better terminated in a BNC as well, but if you are going to go to that trouble for use with a SA and tracking generator you might want to build the unit nicely in a screened box with a good layout to improve the directivity.



Initially it was constructed using all SMD 100 Ohm resistors, but abuse with use fractured them several times (point-to-point with SMDs soldered directly to BNC plugs is a bad idea!), so I replaced the two splitter resistors with leaded ones and kept the SMD ones for the reference load. The original configuration was quite good to high VHF, the leaded resistors only slightly worsening it.



The extra flexibility of the leaded resistors means they will absorb the flexing of the device as leads pull on the connectors without breaking as easily. The splitter resistors are less critical than the reference load anyway, due to symmetry all that really matters is that they are fairly well matched. 1% devices would have been a better idea, but even with the 5% ones the directivity of the unit exceeds 53 dB to beyond 50 Mhz.

The unit has been characterised from 100 kHz to 100 MHz and offers better than 43 dB all the way. Directivity peaks around 3 MHz at over 69 dB, by 10 MHz it has dropped to 60 dB. At 100 MHz it is at least 43 dB but may be slightly better as I am suspicious about the calibration load I was using.

Usage

To use the RLB apply a signal source to the generator input large enough to give several volts of DC out when the X port is open. Larger drive is better as it keeps you away from the diode non-linearity, but don't burn out the resistors. Note the reading on the multimeter, then terminate the X port with a good dummy load, the reading should drop enormously. Note the new reading and divide the original reading by it, take the log and multiply by 20. The result is the bridge directivity in dB. The directivity should exceed the return losses you wish to measure by a reasonable margin for sensible results, ideally make sure it exceeds at least 40 dB and the 0-30 dB RL region is of most practical interest.

Similarly in use, note the unterminated reading, then divide it by the reading once connected to the load under test, take the log and multiply by 20. The return-loss through an attenuator is twice the attenuator loss (through and back, attenuated twice). Return loss is specified as a -ve number by convention, +ve numbers imply gain not loss, but it is common to see RL specified loosely as a +ve figure.

Return loss, Reflection Coefficient (magnitude), and Standing Wave Ratio are all related mathematically and measuring one allows to infer the other two. Here is a table of some common data points:

RL (dB)	|P|	SWR
0	1	∞
1.743	0.818	10
3.522	0.667	5
6.021	0.5	3
5.543	0.333	2
13.979	0.2	1.5
17.692	0.130	1.3
20.828	0.091	1.2
26.444	0.048	1.1
∞	0	1

RL (dB)	|P|	SWR
0	1	∞
2.499	0.75	7
6.021	0.5	3
10.458	0.3	1.857
12.042	0.25	1.667
13.979	0.2	1.5
20.0	0.1	1.222
∞	0	1

RL (dB)	|P|	SWR
0	1	∞
1	0.891	17.391
2	0.794	8.724
3	0.708	5.848
5	0.562	3.570
10	0.326	1.925
20.0	0.1	1.222
30.00	0.032	1.065
40.00	0.010	1.020
50.00	0.003	1.006
60.00	0.001	1.002
∞	0	1

Alternatively you can use my return loss calculator.

Practical Application

One of the first tests I did with it was to measure the line loss of my new coax runs. I spent most of last Saturday running 3 RG-58 coax lines from the shack to the balcony. The job is fairly neat, terminated at each end using BNC bulkhead female-to-female connectors and standard wall plates. The wall plates come from Jaycar and originally had four RCA sockets, which I removed and drilled out the holes to fit the BNC bulkheads. Using bulkheads means good terminations can be made at each end. I had to remove a two bricks from the cavity wall at the shack-end to feed the cable through, a process which took much time and cost some bruises. The real hard part of the job however was at the other end. The eaves are extremely difficult to access from the plenum. I was fortunate enough that a previous device had left a circular hole in the soffit cladding which I reused for this project, but I had to improvise a cable-snake/fish from some galvanised wire to pull the cables through. The access space was barely sufficient for a feline, let alone a larger human, so many more bruises

and Oregon splinters were accumulated in the process. Tanya assisted greatly by feeding the snake from the balcony side, and I complete with knee pads and a head-mounted light source did the fishing job in the plenum.

 XHTML | CSS | CSS toggle

Anyway, a week after that effort the cables were measured for loss. Leaving the balcony-end open circuited the return loss of the cable approximates twice the loss of the line. Of course this is at essentially infinite VSWR which increases the line loss, however this simple test gives a good indication of cable health. The run is only about 30 metres so a homebrew TDR is unlikely to be useful. One of the three runs is from a different batch of cable (I would have run four to utilise all the BNC bulkhead adapters, but ran out of RG-58). This different batch had a better loss compared to the other two runs, but only slightly. Runs 1 and 2 measured almost exactly the same at 1.40 dB at 3.581 MHz (I used the 80 metre beacon TX as a signal source). Run number 3 measured 1.26 dB. Considering these figures where measured at infinite VSWR the lines and terminations seem to be in fairly good condition.

The RLB was then used to measure the match of the 80 metre beacon's antenna after recent improvements in its water proofing. Once tuned up the return-loss is 26.5 dB, which is a ρ of 0.047 or a VSWR of 1.099. It drifts around a little in the wind as the capacitance of the whip varies, this is unavoidable because of the high-Q nature of the matching network to get reasonable efficiency, but the variation is quite small and acceptable.

7 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	12.880 kbytes

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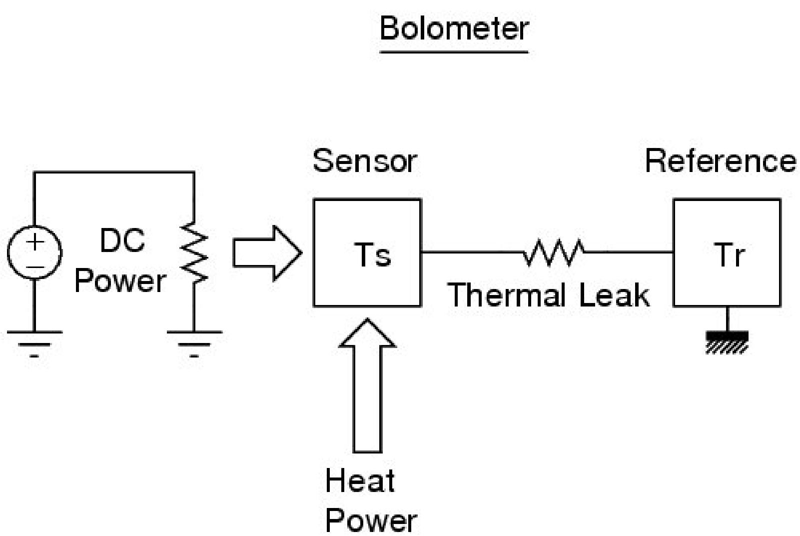
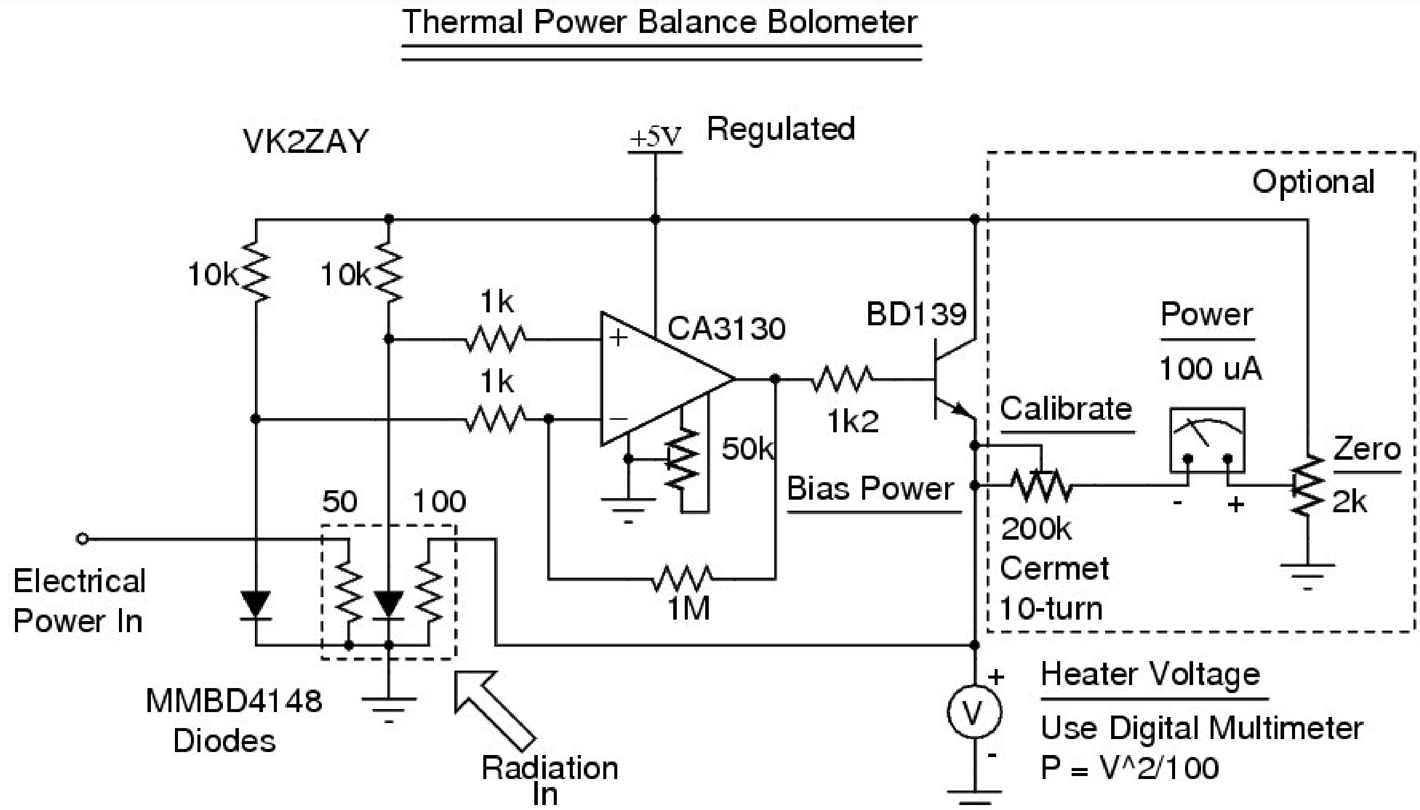
RF and Optical Bolometer

2009-02-25

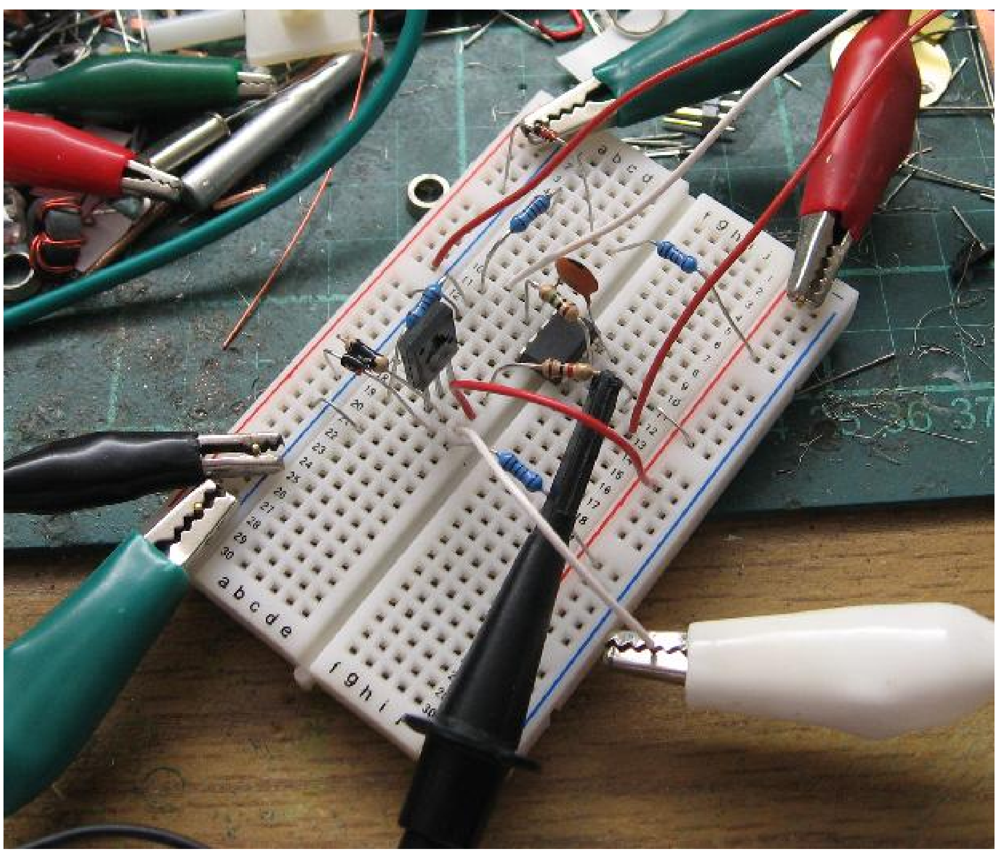
When RF energy is delivered to a resistive load it dissipates heat. If the load has a relatively poor thermal coupling to its surrounding environment its temperature will rise. By measuring the temperature rise it is possible to determine the average power delivered to the load. There are various problems with the approach though, calibrating it is troublesome as ambient temperatures change and many of the coefficients involved are unknown and would need to be determined experimentally. It was during my design of the calibration system I discovered it is fairly easy to just put the temperature sensor and load into a servo loop and maintain a constant temperature above the ambient. In this way the change in DC power required to maintain the sensor at a constant temperature is directly the amount of power delivered to it by other means.



To achieve the thermal control system I started with thermistors but rapidly changed to using common silicon diodes who have a temperature coefficient of about 2 mV/K. An Op-Amp with offset compensation (a CA3130 was in the junkbox) amplifies the drop voltage difference between two diodes and drives a resistor heating element to keep one junction a constant temperature above the other. The amplifier gain is about 30 dB and is not completely open-loop except for the thermal feedback to give it some stability. The circuit in all is very simple and functions adequately for the task.

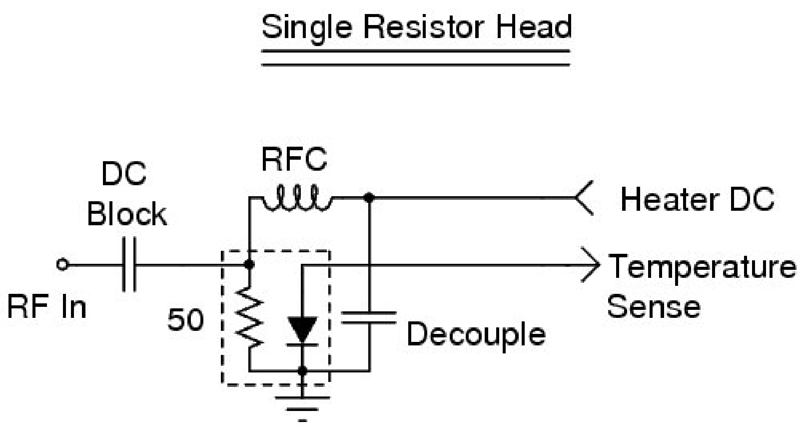


In the first version I used normal leaded components held together with a drop of liquid electrical tape. This arrangement allowed me to test the concept on a solderless breadboard. A centre-nulling meter facilitated "zeroing" the difference by biasing its other terminal to equal the quiescent voltage across the heater. This way I could watch the sensor drift and bias either sensor with my fingers resulting in a swing in the appropriate direction. Such an arrangement **does not** yield direct-reading of power, but can be calibrated at a particular ambient temperature and is handy for trending. For direct reading the absolute power levels in the heater load must be measured and subtracted to yield an accurate figure of power delivered by the external source.

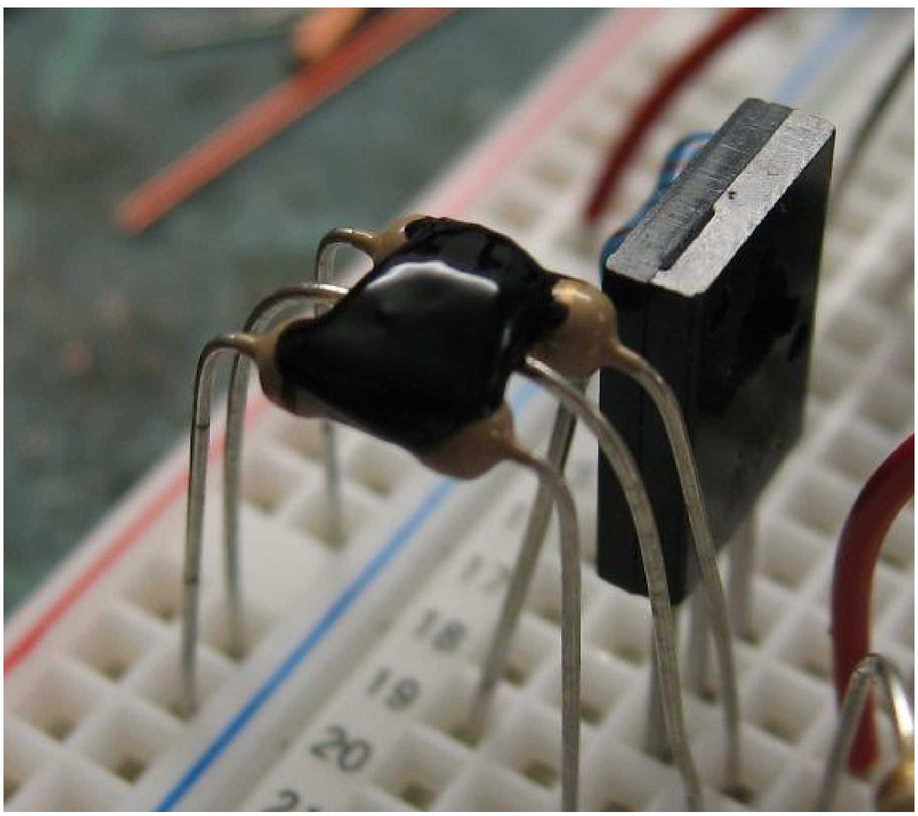


I considered using the same load for RF as the heater. In theory this is quite practical; an RF choke implementing a bias-Tee to deliver the DC heating power while the RF is delivered through a DC blocking capacitor. I wanted to be able to calibrate the device with DC (which is easily

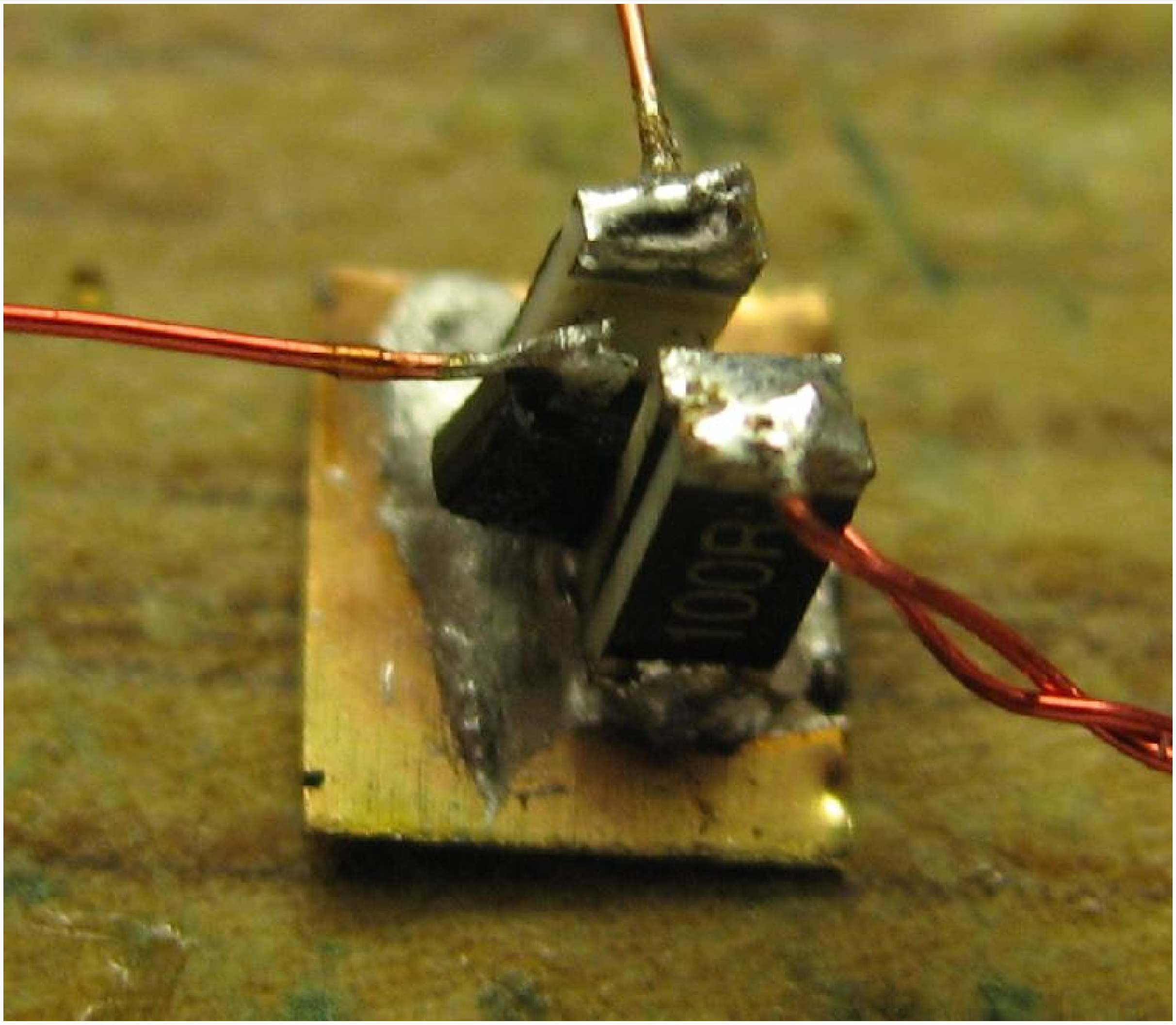
loop. This mandates calibration as the heating effect of the current in each load may not be precisely communicated at the same level to the diode but in practice it was shown to work very well. For RF-only measurement the single heater/sensor system is simple and direct reading (but may require a high heater supply compliance to drive the 50 Ohm load).

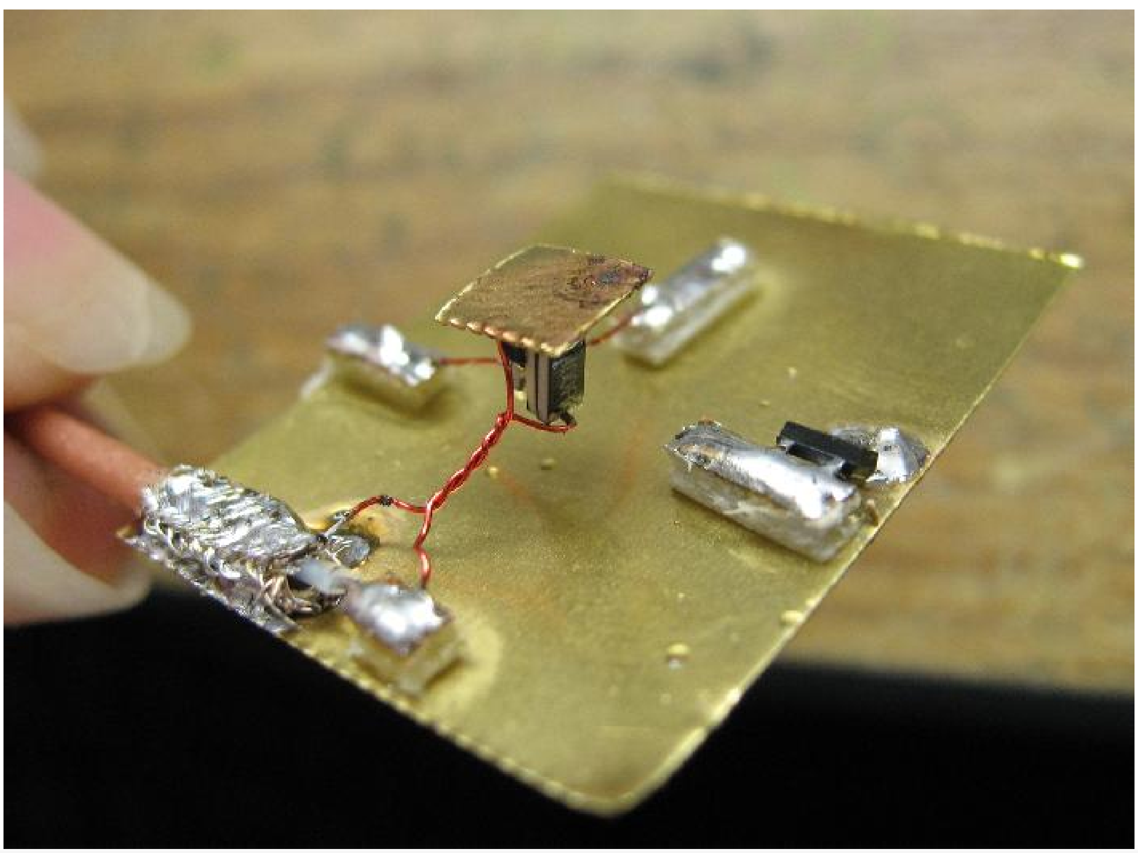


The power delivered to the load/sensor system need not be via the resistor. I discovered external heat sources (like my soldering iron) would produce measurable deflections from quite some distance. This enables direct measurement of electromagnetic radiation that the sensor can absorb. I tried aiming a toy laser pointer at the initial leaded detector arrangement and measured roughly 2 mW of dissipation difference, this seemed consistent with its < 5 mW compliance labelling.



The time constant of the lashed-up detector was fairly long, and to minimise this I decided to build a more physically compact detector. I used SMD components soldered to a small square of brass shim stock. I reasoned the surface area of the plate could be measured and used to calculate optical fluxes. I soldered the SMDs directly to each other after bonding them together with superglue and then soldered their common ground to the plate. The entire assembly was then suspended over a larger brass plate which holds the reference diode. The larger plate can be attached to a physically large heatsink to form a stable ambient reference, while radiation and conduction to the reference mass from the sensor implements the heat-leak required. To facilitate the very low reflectance required for radiation measurements I eventually painted the top side of the brass sensor plate flat-black using Lampblack mixed with a little Red Gum in alcohol to bind it.





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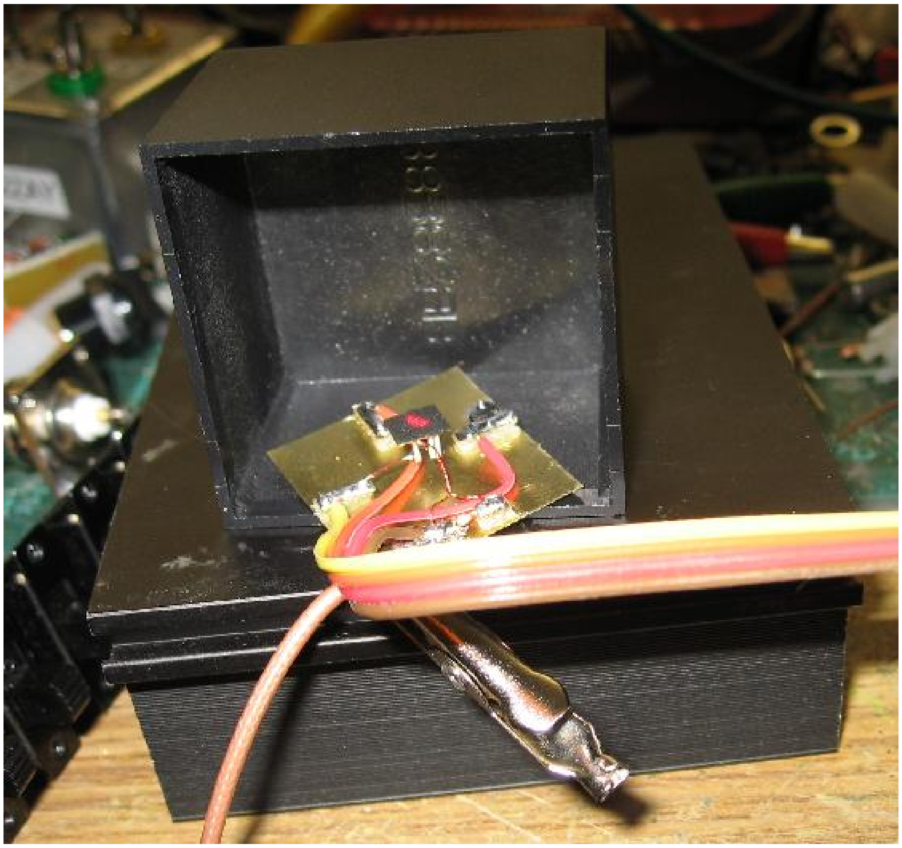
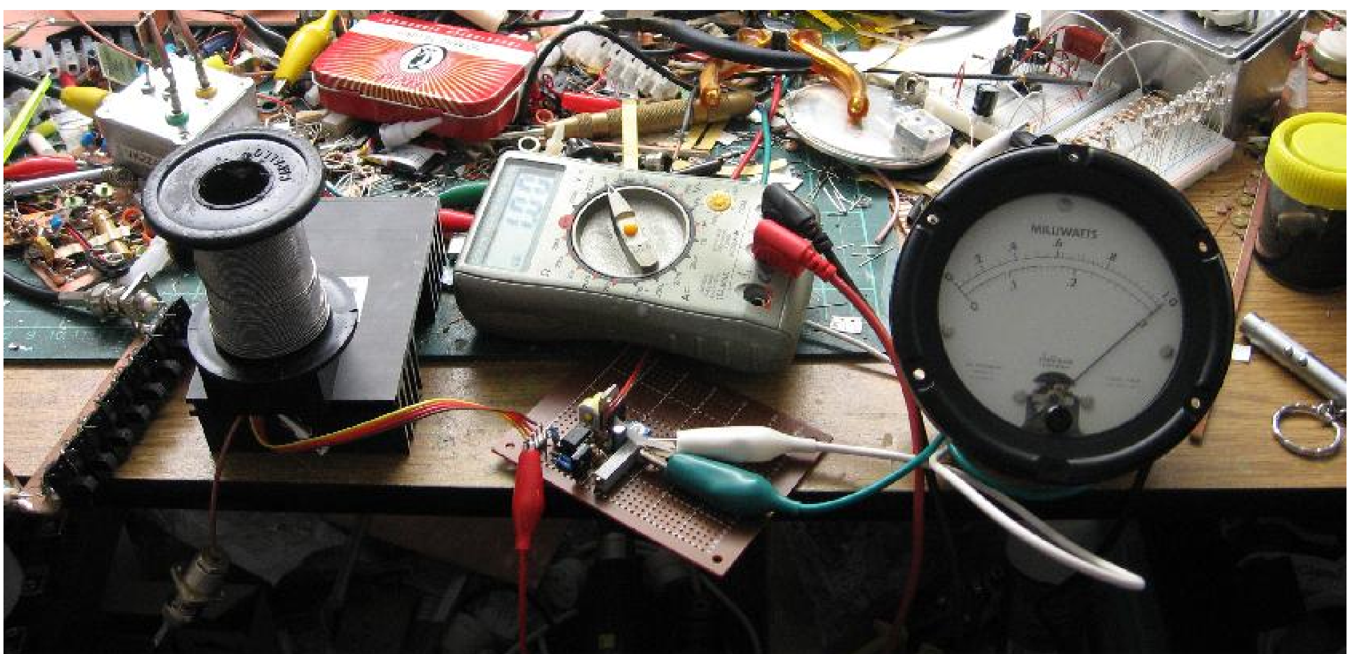
It is important to shield the detector and reference junction from drafts and differences in ambient illumination. The sensor is especially sensitive to drafts and I reason you could calibrate it quite accurately as an Anemometer (kinda neat, no moving parts!), at least at constant barometric pressure. I used a small potting box to cover the detector assembly to exclude drafts. This improved the baseline stability enormously. A small hole in the box allows a radiation beam to enter and hit the sensor plate facilitating its measurement.



With the improved detector the output of the laser pointer was once again measured. 2.4 mW or 3.8 dBm was measured. The DC input from its battery is 72.8 mW, giving it a rather unspectacular efficiency of 3.3%. This concerned me that the sensor reflectance might still be fairly high, but as the compliance data suggests the output is < 5 mW it seems at least consistent. Diode lasers are usually more efficient than that, but the drive electronics is likely wasting a lot of power. I did not dismantle the laser head to directly measure the power delivered to the diode. I'd need a calibrated optical source to check the sensor at optical frequencies. Lampblack should be fairly flat with respect to frequency, at least compared to other "black" pigments. A green laser pointer measured 3.6 mW (5.6 dBm) and is also labelled as < 5 mW. Its IR local oscillator must be filtered from the output fairly well, I was expecting an unusually large reading from its IR leakage.

At RF the detector performs very well and consistently. I measured my 50 MHz "16 dBm" signal source at 48 mW (16.8 dBm) The previous calibration was by comparison to a DC-calibrated diode detector, so I am amazed by the agreement actually. Similarly I measured attenuation steps of a ~100 mW (20 dBm) signal at 10 MHz the results being quite consistent with my previous attempts to calibrate the poorly constructed attenuator at DC.



The system is configured to measure 1 mW to 100 mW, a 20 dB dynamic range. The poor dynamic range is typical of thermal sensors. Its lower limits could be improved by active cooling of the sensor head to achieve more sensitivity and more attention to noise filtering. Its upper limit is really only constrained by the temperature limit of the sensor assembly. I used 125 mW rated SMD resistors and set the bias power a little bit above that level (which is safe due to the heatsinking effect of the detector assembly). With larger resistors in the detector and a suitable power Darlington follower the circuit could be used up to kW. Efficiency is of course terrible, the sensor bias power must exceed the power to be measured. Larger RF powers are more easily measured with diode peak-voltage measurements, but as a thermal device is a natural integrator it can measure the true average power of complex waveforms containing multiple frequencies (including 0, DC biases which may or may not be a problem depending on the application). Attenuation from higher power is probably the most practical method. Amplification can be used to measure smaller signals, but the calibration of the amplifier then becomes an issue. MMICs with reasonably flat gain and compression points exceeding the detector range are available. The load offers a good return loss well into VHF and is therefore capable of absolute average power measurements from DC to several hundred MHz.

The general design can implement all kinds of radiant energy sensors. A pyrometer is simply a matter of optics and calibration. The device is already a fairly usable laser power meter.

Notes

- The heater and load resistors must be as ohmic as possible for best accuracy, although thermal variation in their resistance can be calibrated out. Obviously the 50 Ohm dummy load resistor must not vary too much or else the return loss will be compromised. For most commercial metal film devices the thermal coefficients are quite tiny.
- The "approximately" constant current biasing of the diodes is fine in this configuration, as it is thermal power balancing (not temperature sensing where two different currents would ideally be used to extract the absolute temperature). We don't really care too much about the diode coefficients, just that they hold the sensor at a constant temperature difference to the reference. The reference diode compensates the bias power for variations with ambient temperature. At constant ambient temperature a reference diode isn't strictly required. It is only required that the sensor diode temperature is held constant between zero and applied power conditions for the heater power difference to match the applied power.
- Small decoupling capacitors may be needed across the diodes to prevent RF pick-up upsetting things.
- Watch out for photovoltaic problems with glass encapsulated sensor diodes. SMD encapsulation is not susceptible, but glass cased 1N4148s needed painting black. Not all black paints are opaque at the full range of optical sensitivity of Silicon diodes.
- With a single resistor sensor for RF watch out for magnetic saturation in the RFC core which may drop its impedance dramatically shunting RF and degrading the return loss. Fortunately this is likely to happen with the smallest power inputs so mismatch damage to the DUT is unlikely, but the measurements will be compromised and perhaps go unnoticed. The RFC is problematic anyway, it must have a large impedance with respect to the 50 ohm load across the bandwidth of the instrument - a somewhat challenging requirement for a MF-UHF device. Commercial SMD RFCs designed for MMIC biasing may be useful in this service.
- Larger heating resistances allow the circuit to operate down to smaller power levels, but noise will become a problem.
- Filtering most of the resistor noise out of the bandwidth of the loop is probably a good idea if going for more sensitivity.
- The supply must be well regulated, even with the supply rejection of the op-amp the zeroing for the analogue meter will change (minor) but more importantly the slightly different dynamic resistance of the sensor and reference diodes reflects supply noise into the loop. It might be worth building an ultra stabilised supply for the sensor diode biasing, or even perhaps the entire circuit.
- The heater supply follower temperature coefficient has a small effect and can be minimised by thermal bonding to the reference heatsink.
- At constant ambient temperature the amplifier circuit temperature drift is unimportant, simply measure the change in heater power between quiescent and signal applied to find the applied power.
- The unit must come to thermal equilibrium before meaningful measurements can be made. Fortunately for the small sensor head this happens rapidly (a few seconds).
- Initial adjustment of the bias power should be done while monitoring the heater voltage. Set for about 150 mW of quiescent power and allow to stabilise. Do not set such that the op-amp is pegged out against its upper output voltage limit. Similarly in operation if the input power exceeds the bias power the op-amp will bottom out at near zero volts, the follower transistor will obviously be cut-off a bit before that happens.
- 1/f noise is going to be a major problem when trying to increase sensitivity. It might be practical with extremely small detectors to modulate the heater current and extract the AC response from the diode drop voltage variation and amplify it at that more reasonable frequency. This removes the direct-reading nature of the power balance, and linearity would be compromised based on the diode thermal coefficient linearity around the detector temperature, but baseline drift should be fairly small.

4 comments.

Attachments

title	type	size
Basic Bolometer Scheme Diagram Source	application/postscript	10.429 kbytes
Thermal Balance Bolometer Circuit Source	application/postscript	15.383 kbytes
Single Load Resistor Head Diagram Source	application/postscript	11.452 kbytes

Updates

2009-03-22: Bolometer Head Completed
I finally assemble the bolometer sensor head into something resembling a completed unit.
2009-03-18: Bolometer Baseline Noise Improvement
Gradual improvement of the bolometer baseline noise and the RS-232 sampler data capture system over several days.
2009-03-01: Digital Display for the Bolometer
A multiplexed 7-segment digital display for the bolometer.

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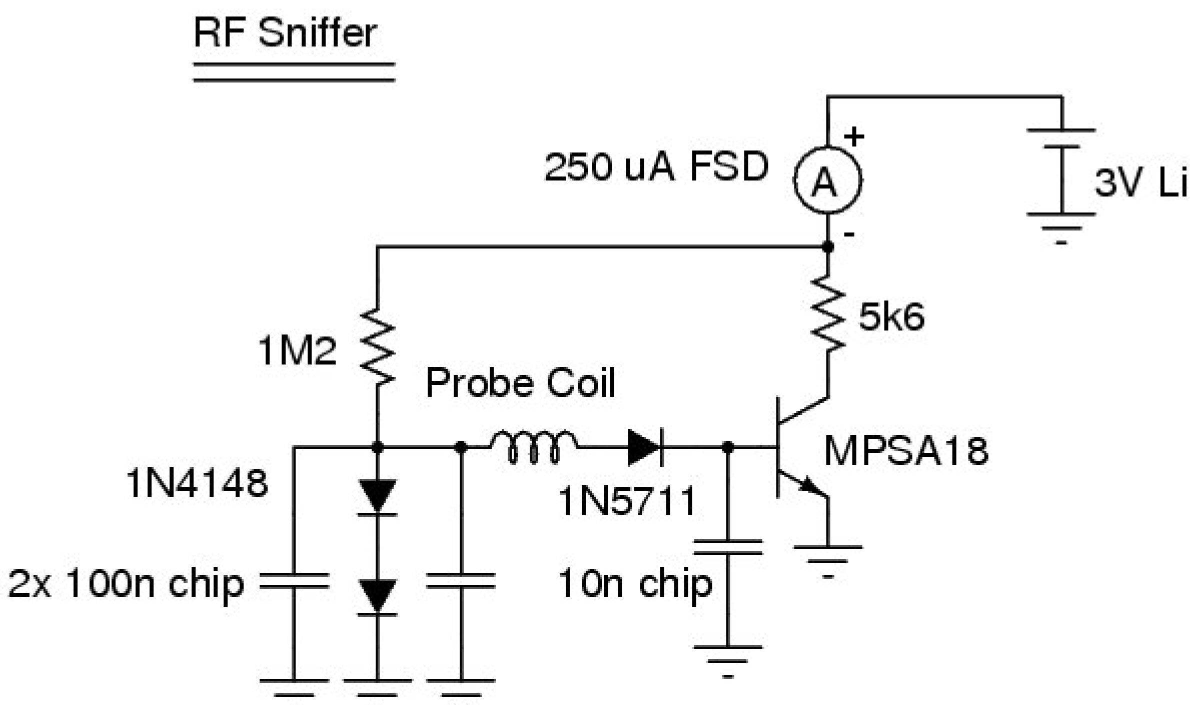
RF Sniffer

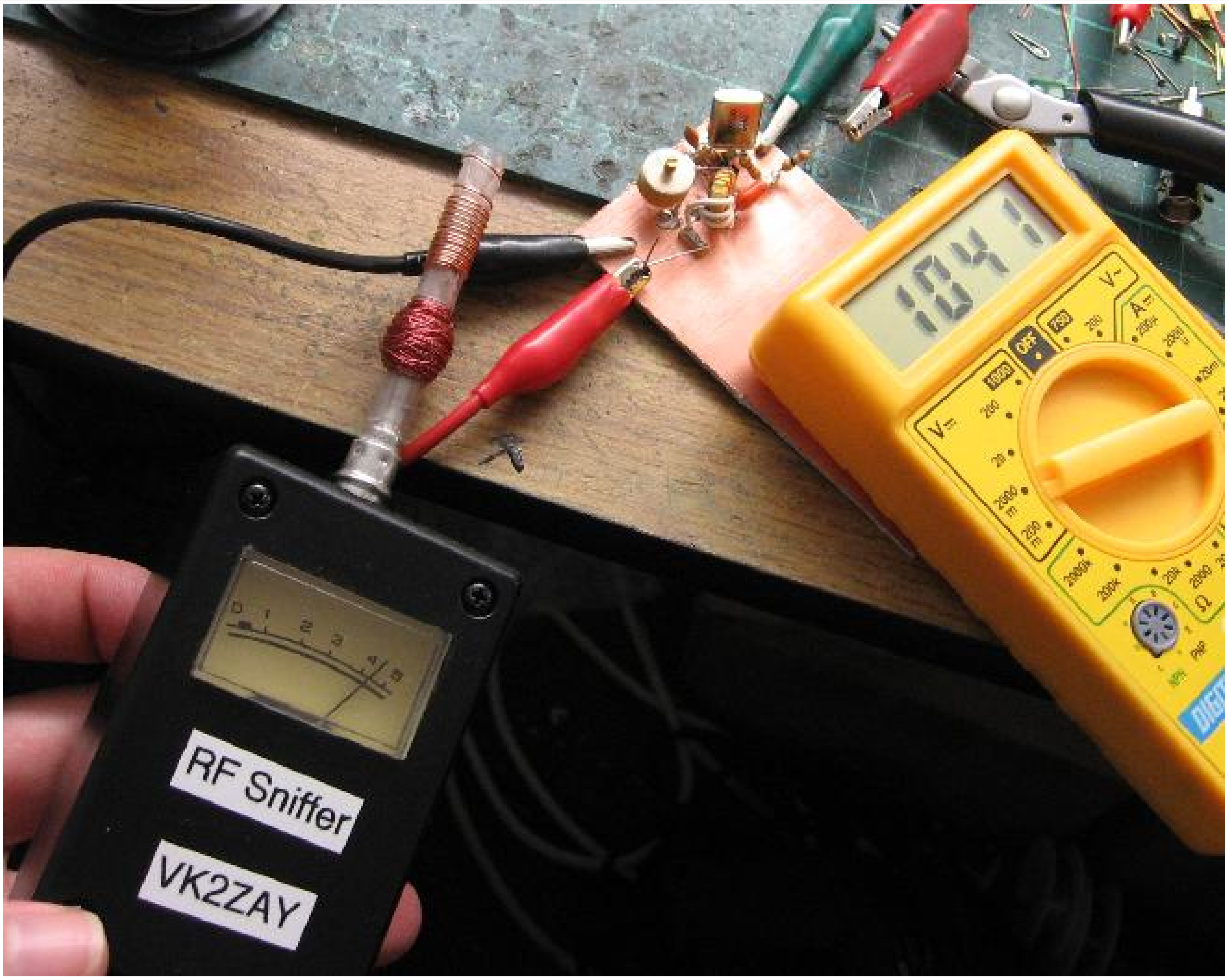
2008-11-17

Yet another circuit based on the biased 1N5711 detector topology utilised in the wavemeter and passive VHF receiver projects. The only two differences in this circuit are the lack of a capacitor to resonate the pickup coil and I didn't add the pot to set the quiescent current, using just the 1M2 resistor to the diodes produced a reading just beyond "1" on the scale with the particular MPSA18 I used. Unplugging the coil is the off-switch, but the current consumption is tiny so I usually leave it plugged in.



The pickup coil is slightly exotic, having a jumble-wound LF/MF choke in series with a HF/VHF coil with a varying pitch along its length. The general idea was to try and produce an probe with several resonances in key bands to make the unit more generally usable with the single probe coil. The turns are held in place by dipping the coil in molten wax. Other coils can be attached, it uses an RCA socket like the HF wavemeter and the two units can share coils. I have several for specific purposes. Sensitivity peaks at the self-resonance of the coil and the stray capacitance of the circuit. The hybrid choke probe works fairly well from LF to SHF.

 XHTML | CSS | CSS toggle



The microwave oven and WiFi base station are easily detected, showing the units SHF response. My various HAM transmitters happily slam the needle across HF to VHF and UHF. It picks up SAW-locked UHF keyfob transmitters, and even stray MF radiation from the LED multiplexing on the air conditioner control panel. LF radiation from 256 kHz contact-less proximity card readers is detectable quite a distance with the hybrid coil.

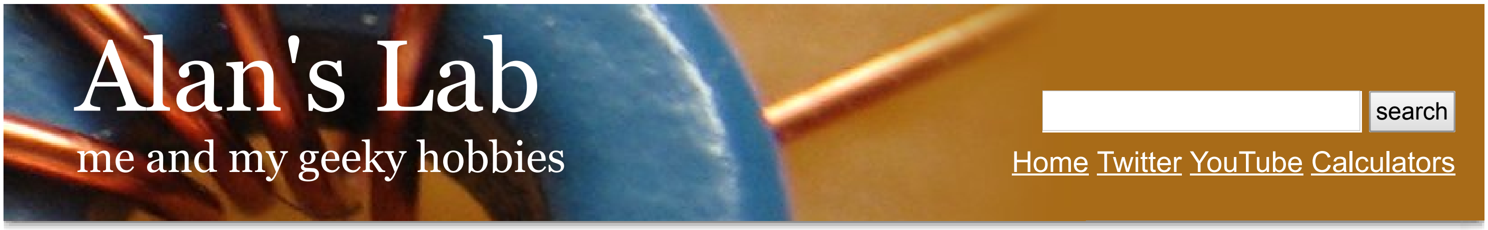
It is often too sensitive, and a way to vary the sensitivity would be useful. A 5-10k pot in the right place would do the trick if you are building your own. This would increase its usability as a stray-current tracking tool in antenna work. A probe comprising a split ferrite toroid (clamp-on current probe) would also be quite useful but I haven't had the need to build one yet.

Probably the most common use is just to see if an oscillator is making RF. For this purpose it was originally constructed: While experimenting with UHF oscillators around 1.5 GHz, the sniffer was used check the oscillator output, and to detect nulls while playing with Lecher lines.

27 comments.

Attachments

title	type	size
Sniffer Circuit Source	application/postscript	12.490 kbytes

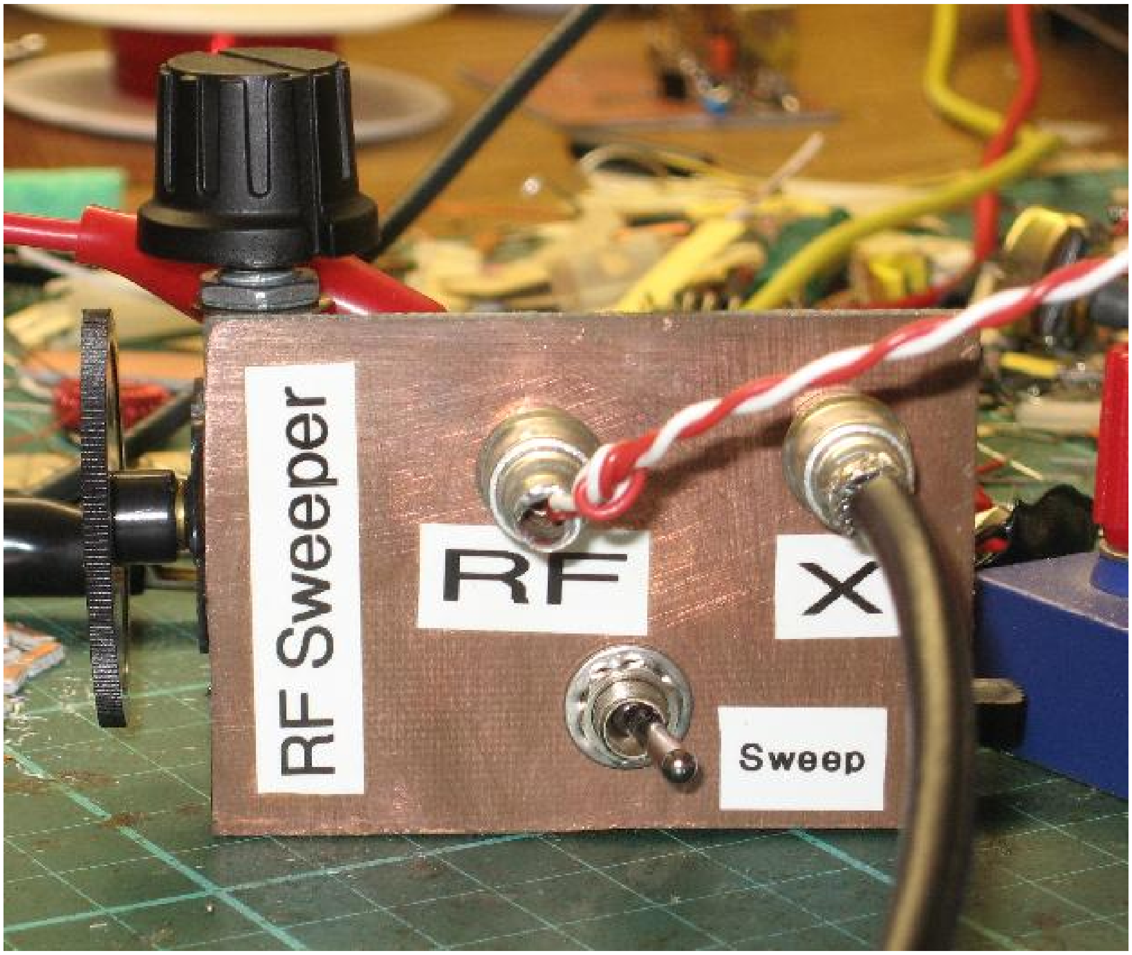


search

RF Sweep Generator

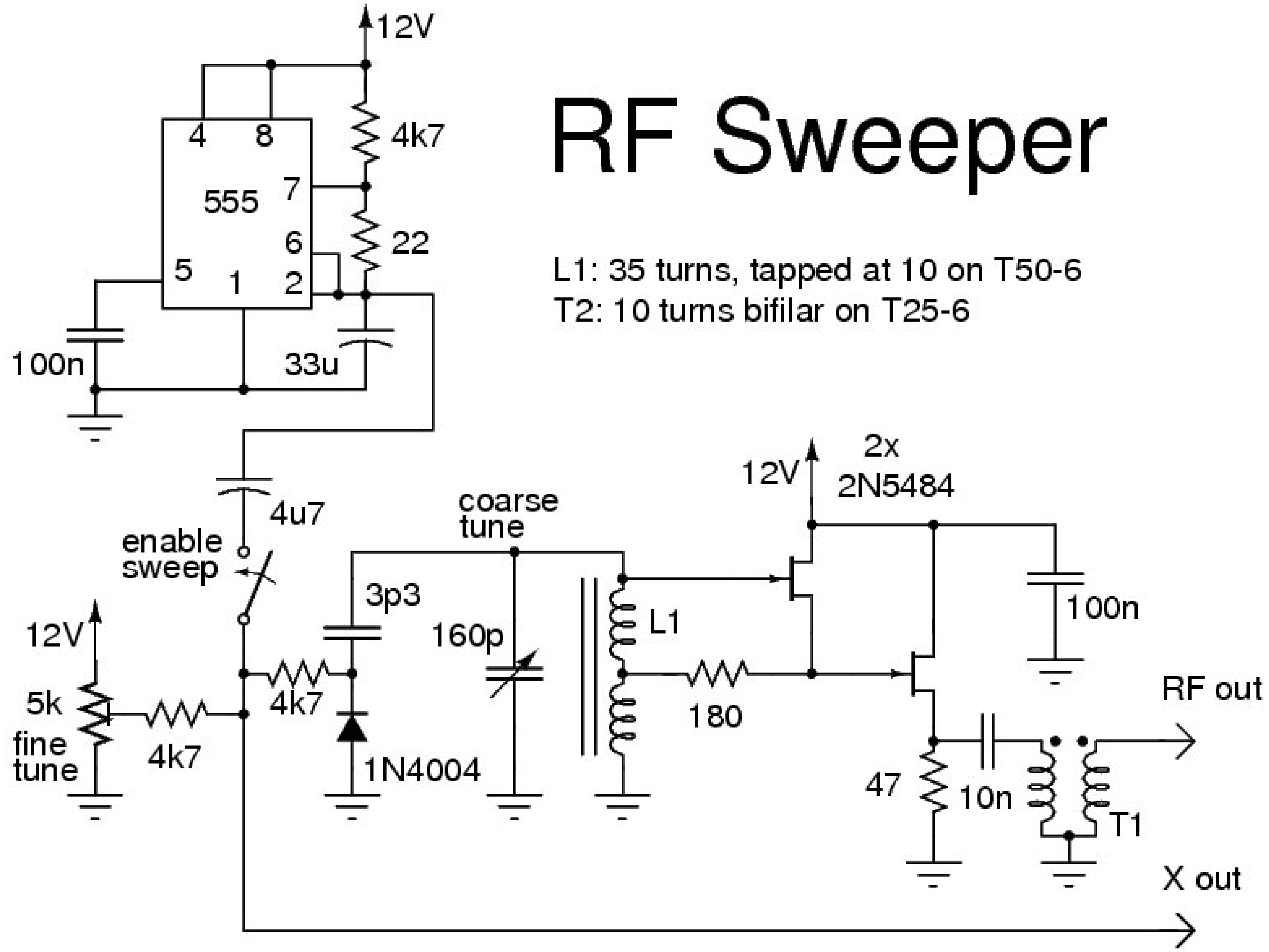
2006-11-04

This simple tool has vastly expanded the kinds of projects I can undertake. My only recommendation is that you build it, or something similar. Without it making crystal ladder filters is next to impossible, and it finds other uses, like sweeping IF strips, filters, even antennas with the help of a simple resistive bridge.



For a long time I've been wanting to build an RF sweeper, the VK5BR one in particular still holds my interest. It is quite elegant with the calibrated width and external generator mixing. However, JF1OZL's unit is far simpler to build, it took me only 2 hours to hack together my copy. Despite a few drawbacks which I'll discuss shortly, it is one of my most useful pieces of test equipment.

The core of the circuit is a VCO based around your basic JFET Hartley oscillator. The oscillator is buffered once with another JFET and the signal coupled out via a bifilar transformer. The VCO functionality is implemented with a varicap diode, the timebase being a simple 555 timer IC.



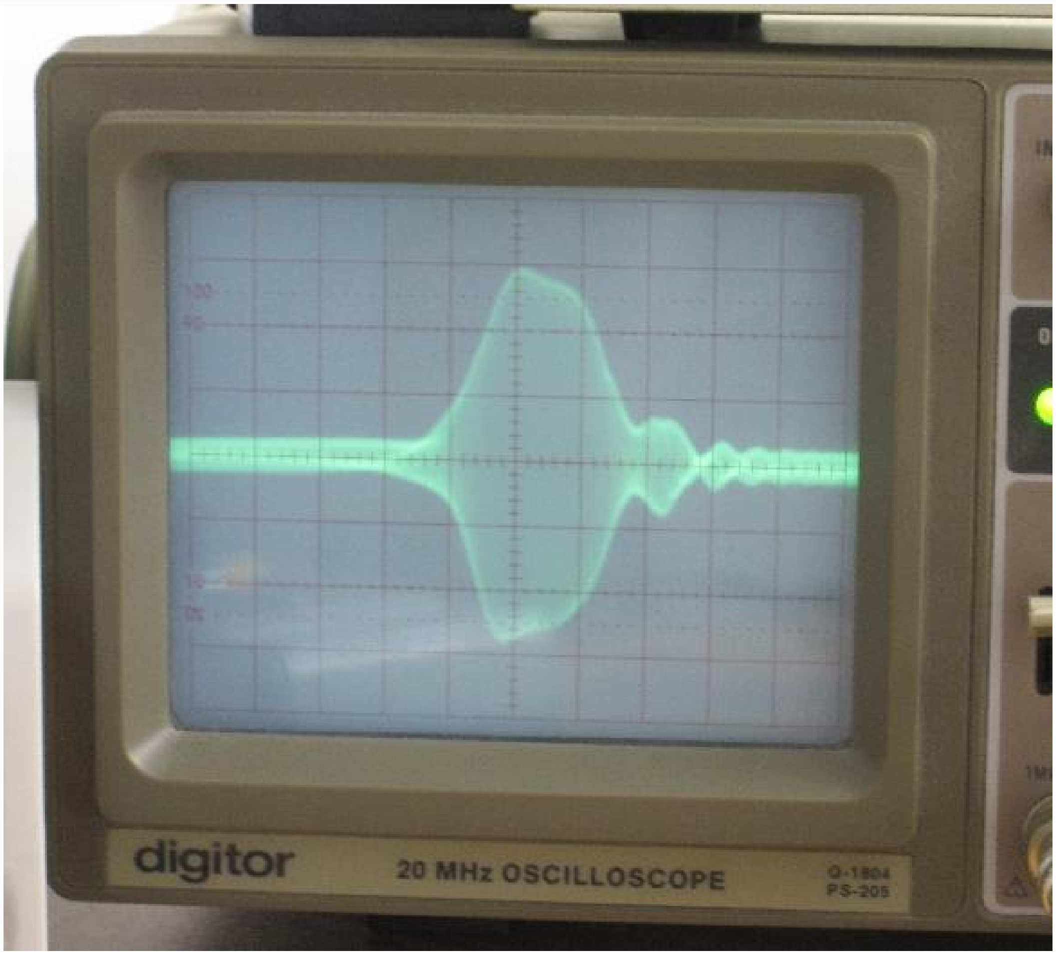
I used a 1N4004 as my "varicap" diode, and 2N5484 FETs. A plastic AM-radio tuning gang for the frequency adjustment. JF1OZL uses a pot for a fine frequency control, but only when the signal is unswept, I decided to arrange mine to bias the varicap at all times, and apply the timebase signal through a capacitor so the frequency swings either side of that set by the combination of the tuning cap and the bias on the varicap. Obviously this has linearity issues and width of sweep limitations, but the arrangement works quite well in practice.

My unit tunes 4.5 - 13.7 MHz with the values indicated.

If you need variable sweep width, or a wider sweep in general, you can replace the 3p3 coupling capacitor with a trimmer. If you require a more narrow sweep than can be provided by the minimum capacitance of your trimmer, pass the timebase signal through a 5k pot to reduce its amplitude before it is applied to the varicap (you may also wish to increase the 3p3 coupling cap and control the width purely by the amplitude of the timebase signal - you may also want to limit the range of the DC fine control signal to keep the varicap biased within a fairly linear region). Unfortunately this can not be directly calibrated in width, as the effectiveness of the capacitance varies with the main band-set capacitance setting. You could use a fixed frequency for the generator and add a mixer at the output to implement something quite similar to the VK5BR sweeper, which would then allow direct calibration of the sweep width.

I did not implement the additional output for a frequency counter. Instead I generally tap a 2-pole 12 dB pad at the 6 dB point and feed the counter from that. If I rebuild the unit, I will probably add an additional buffered output for the counter.

Here is the trace of a 11.98 MHz crystal filter I was tuning using the unit. The -20 dB width is about 4.5 kHz. You can determine this by turning off the sweep and using the fine tune control to rock the oscillator across the bandpass manually. Combined with a counter (and it is handy to be listening to the signal on a HF receiver) you can note the response and measure the circuit bandwidth.



Limitations

Retrace can be a problem, smudging the trace on the CRO. I think a blanking circuit would solve this, and could be easily implemented by taking the output from pin 3 of the 555 and using it to switch the RF output or the detected signal fed back into the Y-input of the CRO.

The oscillator buffering is insufficient. The load can pull the oscillator, at times quite badly. For example, crystal filters have been known to pull the oscillator so much it simply refuses to tune through the series resonance of the filter. The oscillator will jump more than 1 kHz over the "dead-short" region of the filter, going in either direction no matter how carefully you tune it. This is apparent even with a 12 dB pad between the generator and the filter. Fortunately this is fairly simple to fix, and it my silly choice of a Tx-6 core for the output transformer is largely responsible. This should be a FTx-43 ferrite core, not a powdered iron one. But the buffering should be improved, probably by adding another stage, BJT based I think, and an internal pad.

The trace isn't linear. The timebase wave-shape is 1st order exponential because the simple 555 timer circuit charges the capacitor via a constant voltage source. Implementing a better timebase with constant current charging (say an op-amp triangle generator or FET current source relaxation oscillator). This would improve the display by making a linear scan. However, this is only half the problem, the "varicap" isn't remotely linear, especially for wide scans. This can be improved by careful biasing after characterising the diode in question, and using relatively small voltage deviations to approximate linear V/C characteristics. Obviously the rest of the circuit would need to be modified to support this. I just put up with the non-linearity, as shape is generally what I am looking at, not absolute width.

11 comments.

Attachments

title	type	size
Circuit Diagram Source	application/postscript	17.404 kbytes

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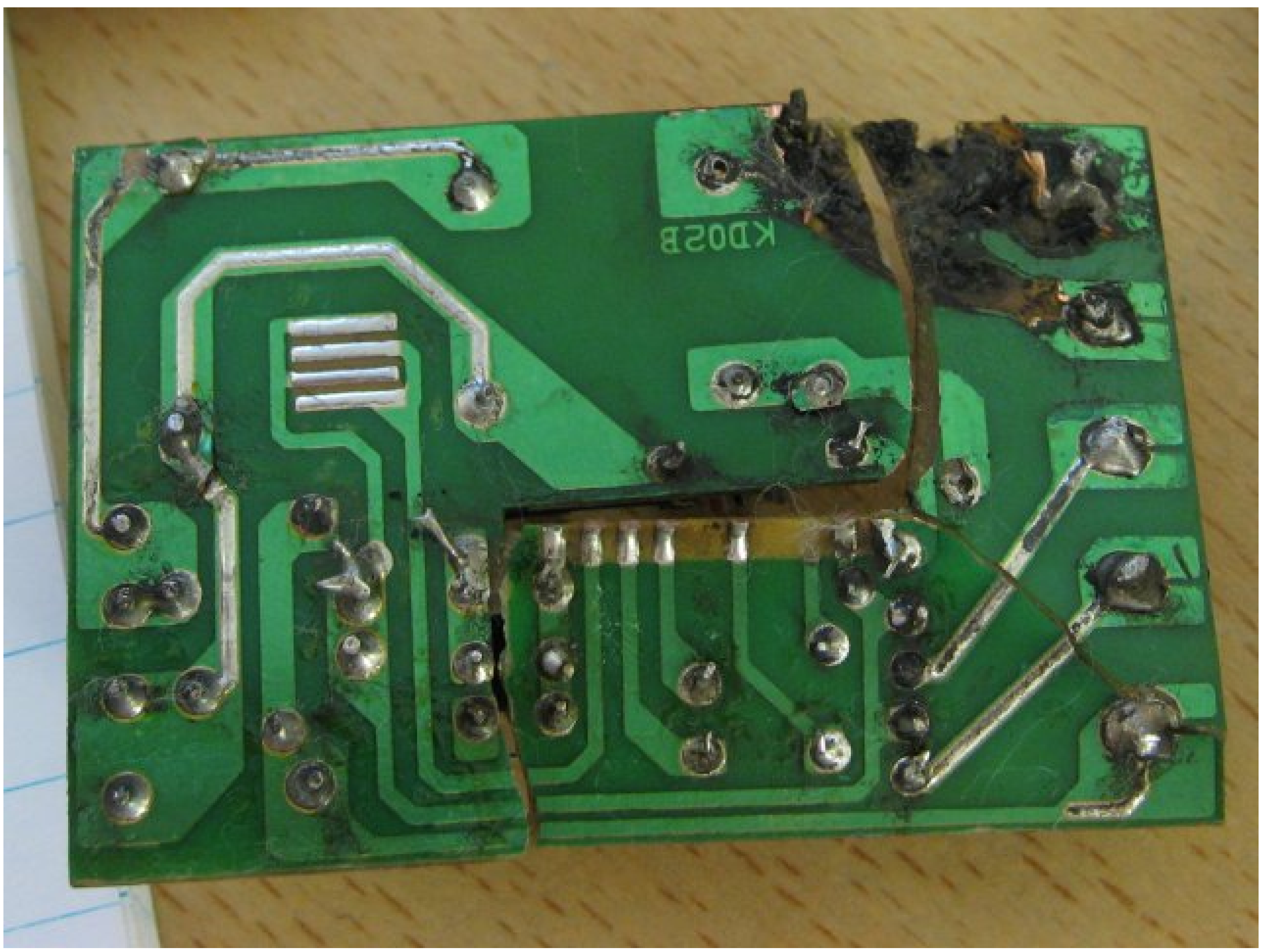
Rope Light Controller Failure

2010-01-04

The commercial Rope Light used in the [Christmas Star project](#) stopped working suddenly. The usual checks failed to revive it or indicate a reason for the failure so the sealed controller box was opened. Opening it was quite challenging, eventually I simply smashed the heck out of the box glue joints with a big hammer. Unfortunately this rather brute-force approach applied forces and accelerations to the internal components that were beyond their limits. The phenolic PCB was smashed and the heavier components torn off the board.

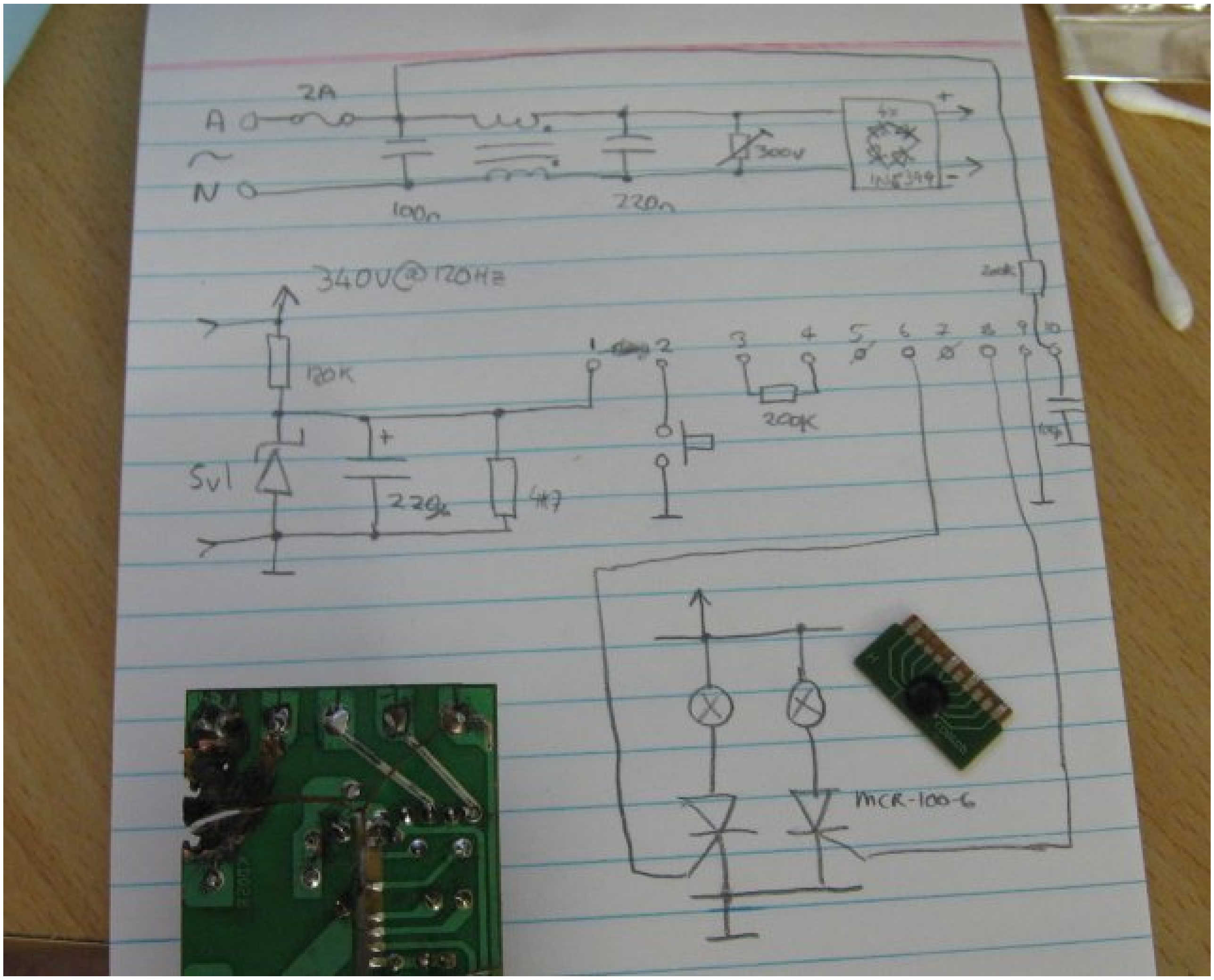
Even before completely gaining access it was immediately obvious by the smell that something rather catastrophic had occurred. A small amount of black fluid leaked out as well, indicating the likely cause for the failure was rain water penetrating the "outdoor" control unit. Upon inspection of the PCB there was extensive charring around the mains ingress point and foul-smelling, greasy pyrolysis products coated everything inside the box. Cleaning with water didn't shift the blackening, but 2-propanol made short work of it. The full horror of the failure was then evident; an arcing fault had occurred directly across the mains carbonising the phenolic board and spraying copper everywhere. The fault occurred before the internal fuse and did not open it, rather it appears to have burnt itself open, as the 30 Amp circuit breaker to the mains circuit in question did not open. It was probably only its containment in the sealed unit that prevented a much more violent event and resulting fire.



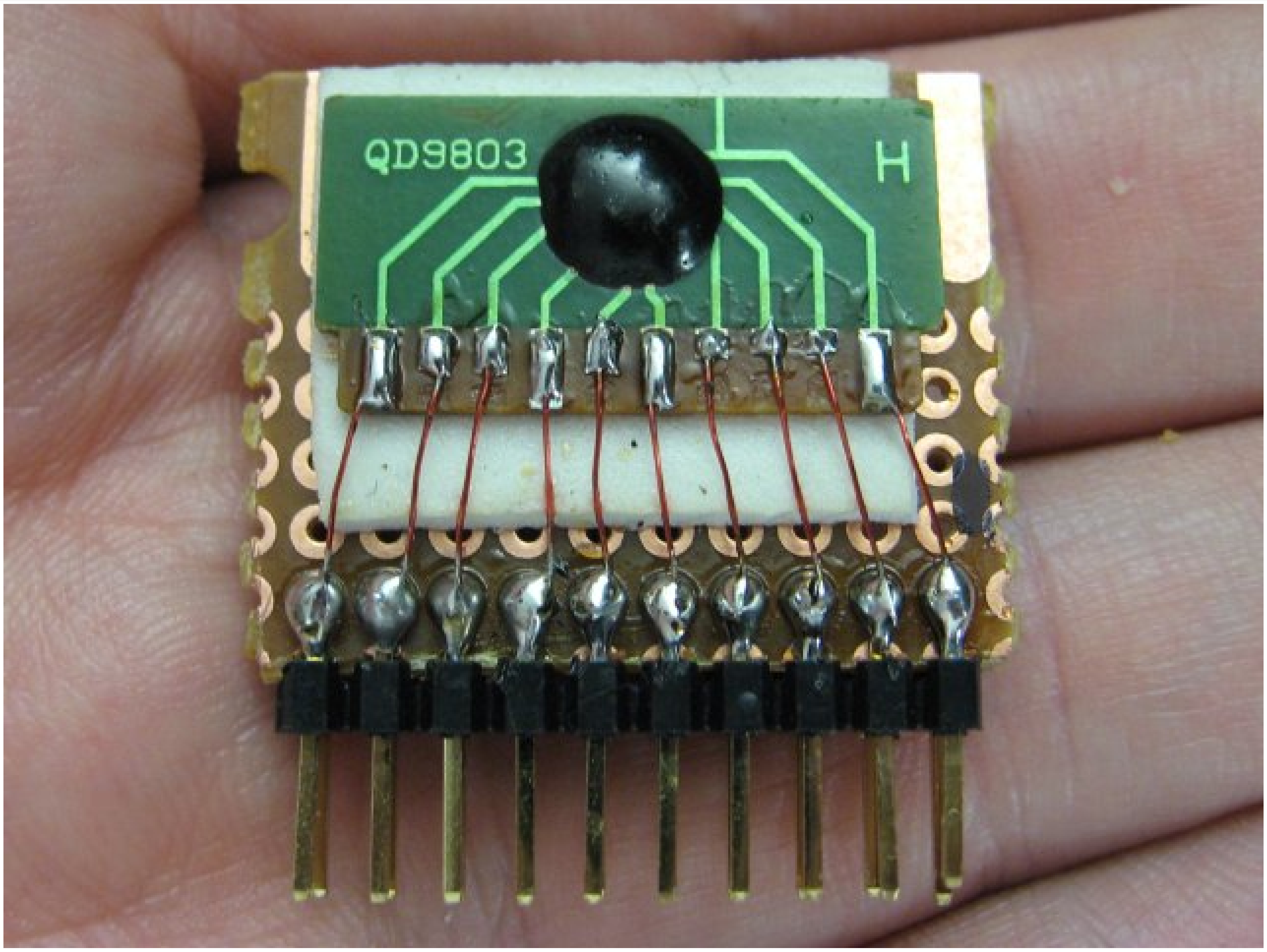
Despite my rather kinetic opening technique it was relatively easy to trace out the circuit and study it. The unit is a phase-angle controller, using SCRs to switch the bridge-rectified mains into the two circuits of the rope light. The controller logic is a small 10-pin SIP daughterboard with a die packaged directly to it covered in the familiar black encapsulation. The controller runs off a 5 volt rail derived directly from the rectified mains via a high-wattage dropper resistor, a 5v1 zener diode and a 220uF electrolytic capacitor. There is also a leading resistor

 [XHTML](#) | [CSS](#) | [CSS toggle](#)

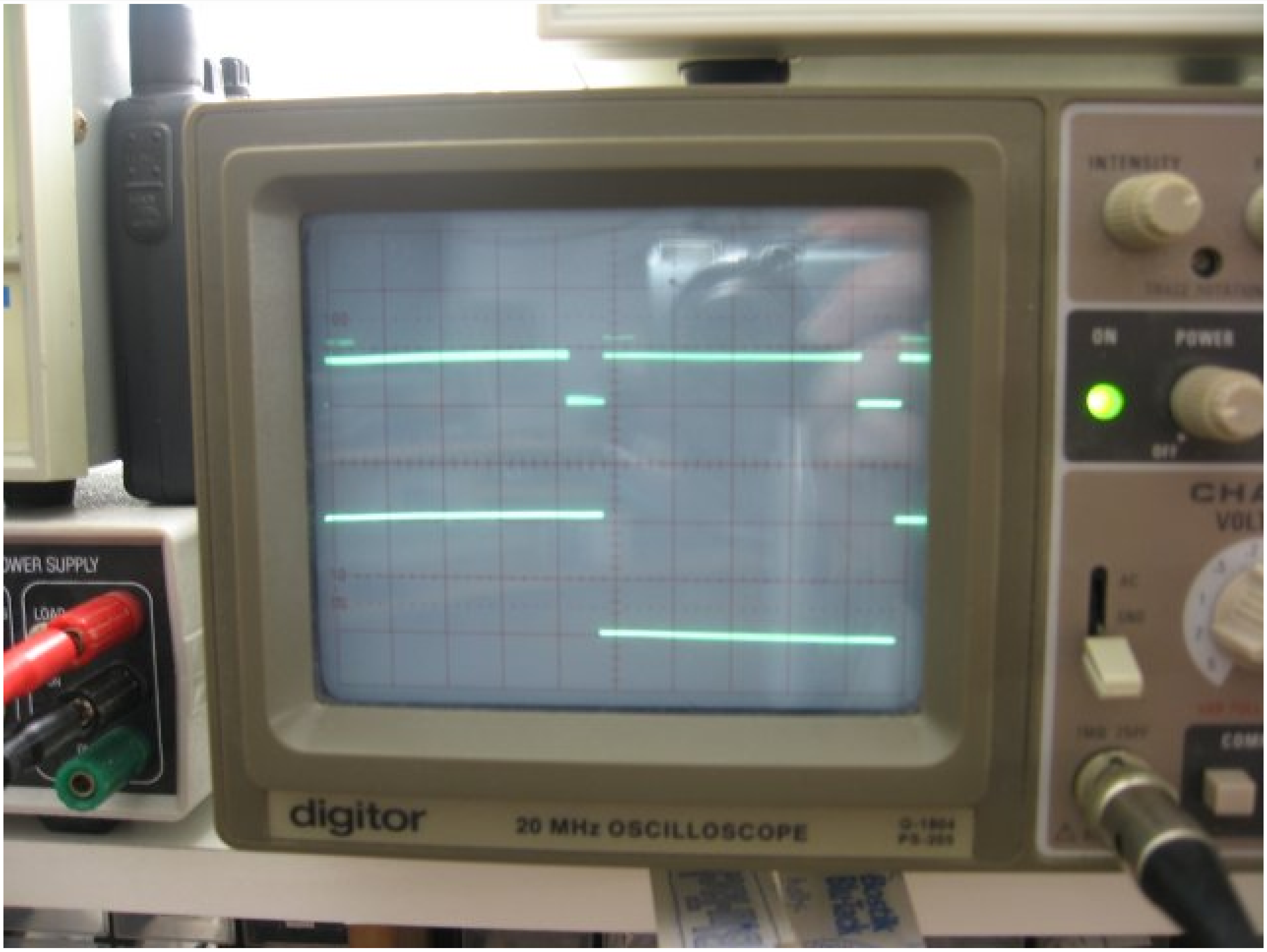
are driven directly from pins on the controller card, suggesting it has internal current limiting. There is a fairly substantial EMC filter on the mains side, with a common-mode choke and filter capacitors across the mains. There is also a MOV suppressor. The active feeds the controller a phase reference through a 200 K resistor and a 100 pF capacitor to LPF it.



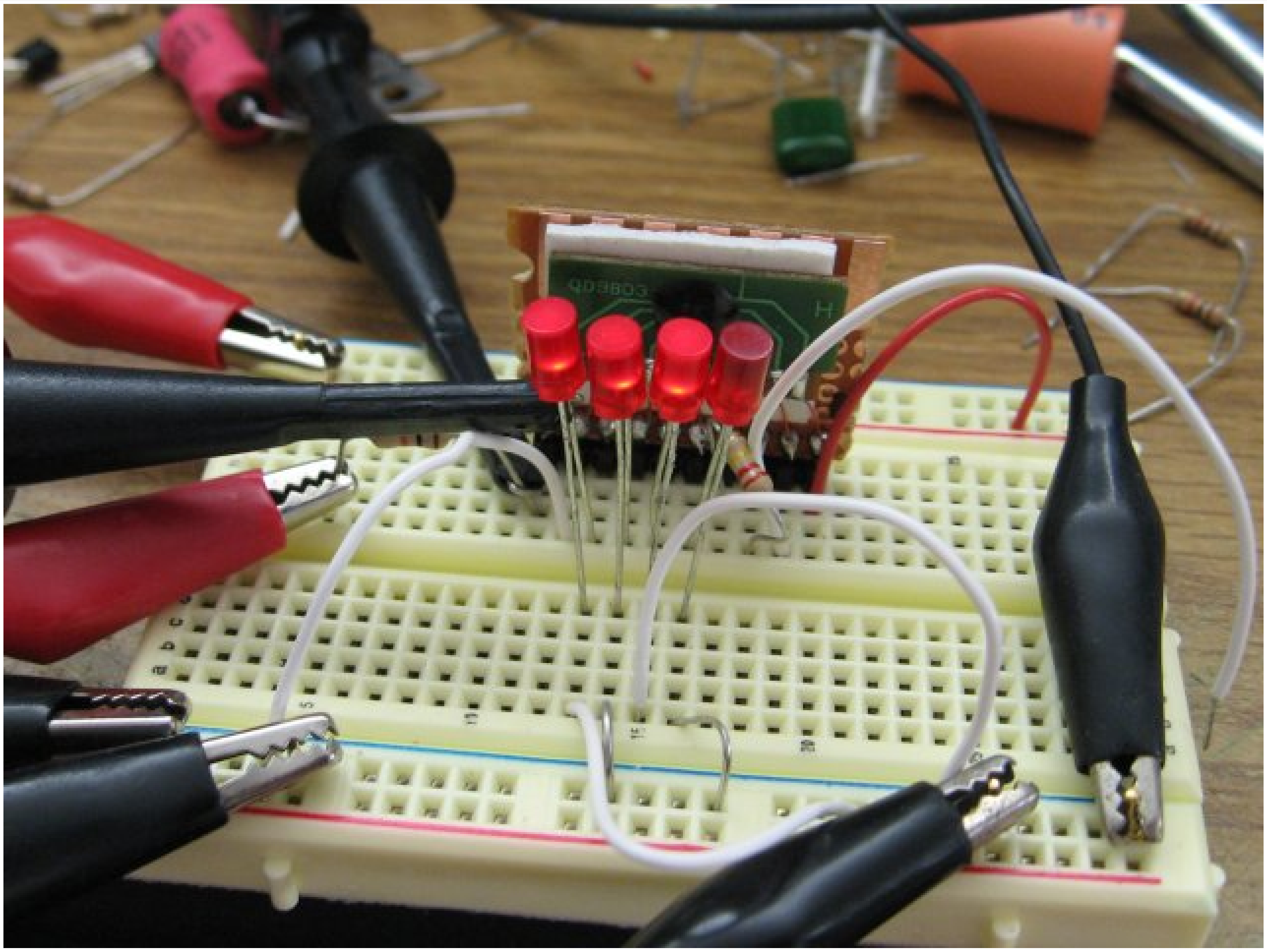
The controller daughter card had some minor damage to its track-work thanks to my aggressive access method, but being a metric pitch required a little effort to test. I wired it up to a "standard" 0.1-inch header with the wiring pencil and plugged it into a solderless breadboard.



Once supplied with 5 volts, its timing resistor, and a zero-crossing reference I quickly determined it was a 4-channel unit (with the rope light only utilising channels 0 and 2) and was undamaged by the fault. The clock is about 115 kHz and varies quite dramatically with the timing resistor. It appears to be matched to the mains frequency, the zero-crossings of the reference synchronising its internal state so the control signals are phase-synchronous to the mains waveform. With smaller timing resistors it will happily generate several gating cycles per mains half-cycle, but it realigns upon the next zero-crossing. Larger timing resistor values compress the available phase-control range. The standard value 220 K is a little too large for 50 Hz, the supplied value in the original circuit (200 K) is also slightly too large, but wastes less of the waveform tail. The 100 Hz frequency of the full-wave rectified mains makes the fading quite smooth and flicker free, probably even with LEDs. It would not surprise me if this particular device is used with the typical 24 VAC LED lights as well. The gate drive signals are high for the entire conduction time, so they could drive non-thyristor switches too. There are a series of transients just after the leading edge of the drive lines going high, their purpose, if any is unknown? They exist into resistive loads but appear inversely proportional to current delivered (from a slightly higher impedance than the main logic level itself).



The drive outputs source enough current to directly drive LEDs, so I plugged some in. Not sure how much the outputs can sink, I didn't want to push my luck with what was clearly a working unit.



Now the choice becomes, do I rebuild the controller, returning the rope light star back to service? Or do I simply hard-wire the rope light straight to the mains (through a fuse) and have a static star? Another alternative is to chuck out the rope light and just buy a new one in December... Surely the time saved would be far more than the $22 price tag of the rope light - but that is never why I build things for myself anyway. I think I've had enough of blinken light projects for a little while, time to build some RF stuff again! Might get around to rebuilding it eventually though.

6 comments.

Parent article: Rope Light Christmas Star.

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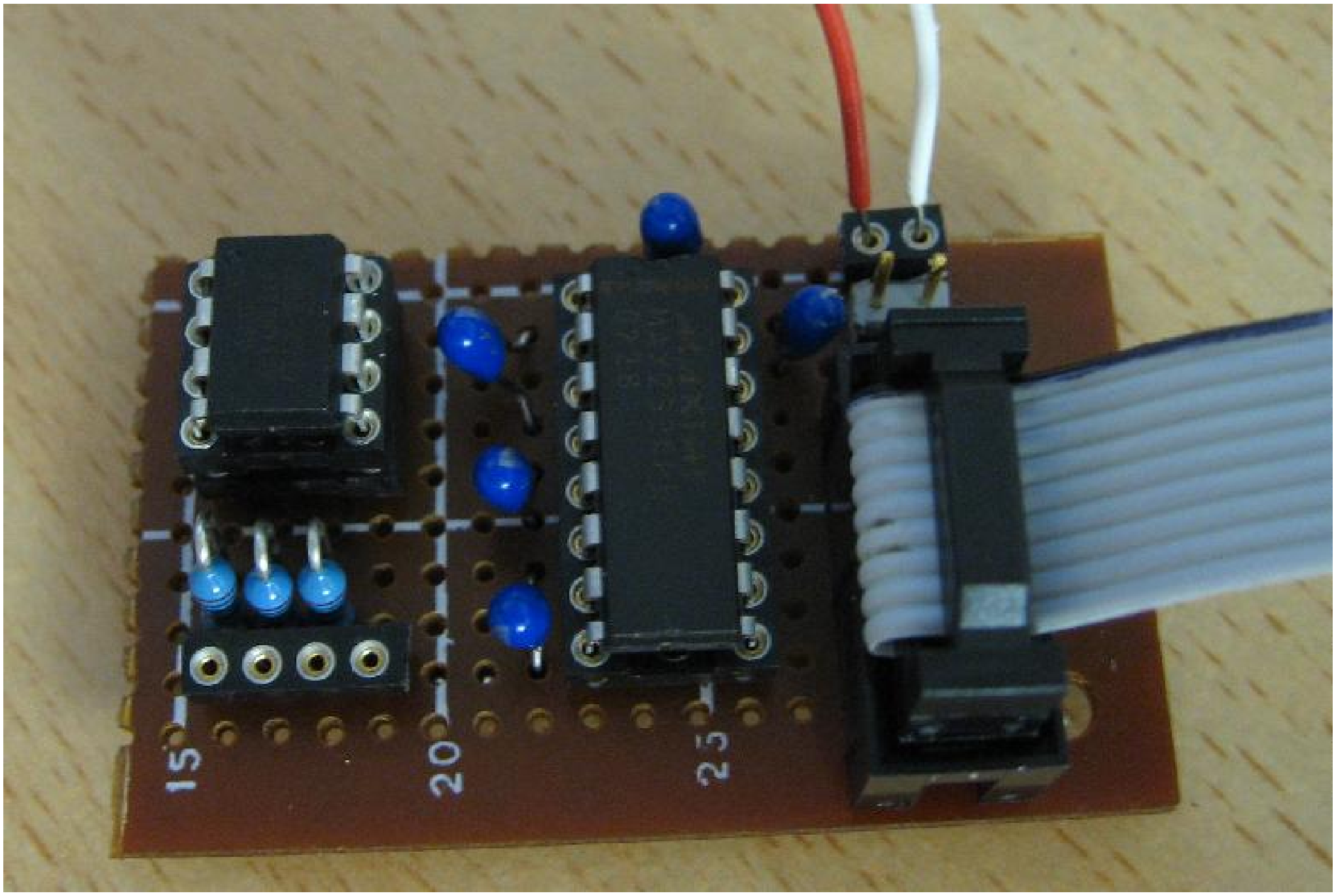
search
Home Twitter YouTube Calculators

RS-232 ADC Sampling Interface

2009-02-27

Sometimes you just want to sample a DC voltage periodically and log the results on your PC. The Atmel ATtiny13 has a four-channel multiplexed 10-bit ADC capable of sampling at up to about 15 kHz. Its small package, low cost, and modest program memory seem to make it ideal for a quick 0-5 Volt sampler feeding a PC. However, the ATtiny13 doesn't have a USART, so getting the data out of the device requires a little bit more effort than with other AVRs.



Software

To get around this lack of dedicated serial IO hardware I simply implemented serial TX in software. The tiny13 counter is set-up to interrupt the processor at the baud rate, a simple state machine bashes out the serial signal on a digital IO pin when there is data to send. The CPU spends most of its time asleep either in idle or ADC noise reduction mode.

Unfortunately the lack of an additional hardware counter means timing the ADC sampling is not very easy. As the application is simply "sample at a reasonable rate" (quazi-DC logging use) rather than a precise rate this is of no consequence, but perhaps with more work on the software it would be possible to specify the sample rate. The sample rate is deterministic, but as I am using the internal 9.6 MHz oscillator the rate isn't completely stable (an external clock could be used if so desired, at the cost of an input channel). There is also a phase-shift between the channel samples: ADC conversions are executed in series (because there is only one ADC in the chip). After all conversions are complete the results are converted into decimal text and sent down the serial line. Once the data has been sent sampling begins again. The full 10 bits of ADC data are delivered, the software in the PC can truncate the data if that level of resolution is not required. The text format is simply a line of four decimal numbers, the first is a monotonically increasing number (the number of ADC conversions executed since reset), the following three numbers are the ADC data 0-1023, finally a CR LF pair terminates the line (canonical text):

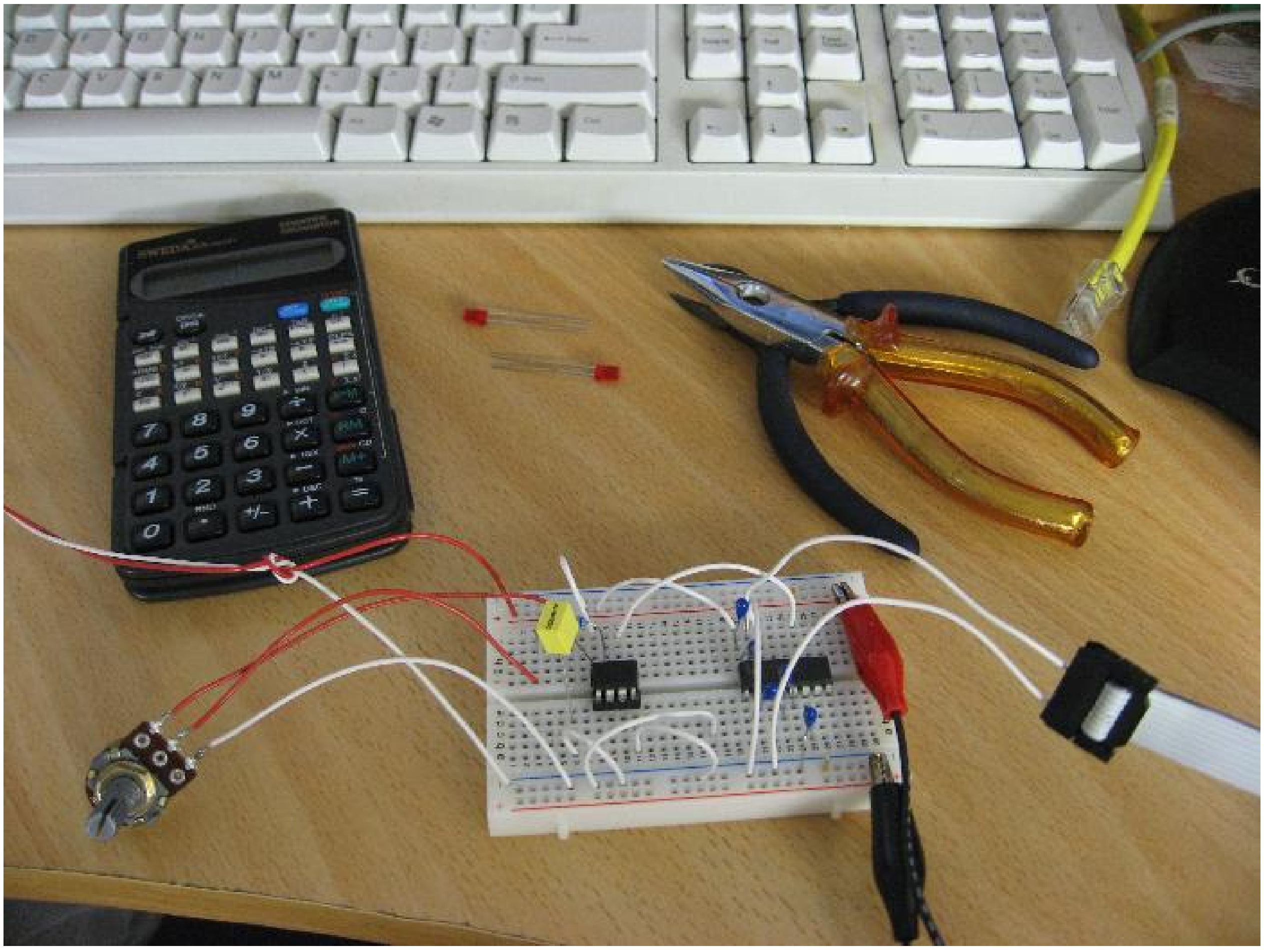
```
32745 445 440 413
32748 448 442 422
32751 453 446 434
```

```
32757 465 461 458
32760 468 465 464
32763 470 470 467
```

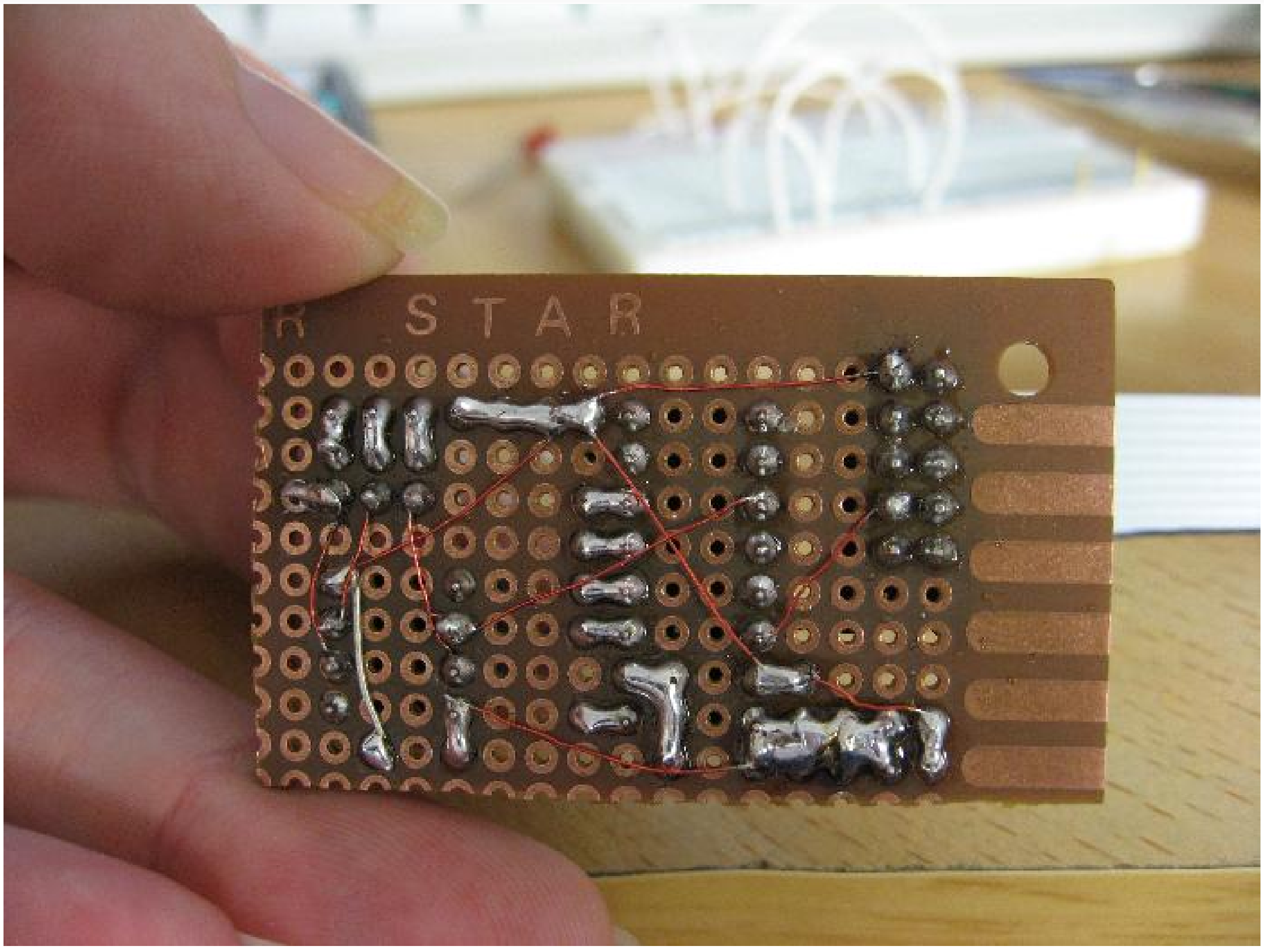
The fourth ADC multiplexer channel in the tiny13 requires the reset line to be dedicated as an IO pin. Setting this fuse breaks simple serial programming, so I chose to use only three of the available four channels. You can alter the code if you don't mind HV programming, or if you want to sample less channels (faster). The baud rate could be increased, but eventually the jitter of the internal oscillator will start causing problems. 9600 is fast-enough for my current uses.

Hardware

For RS-232 signal level conversion I use the trusty old MAX232 (as I happened to have some in the junkbox). More recent chips require less external capacitors, or even none at all. Analogue input protection is quite primitive, just a 1k series resistor. It is expected the sensor amplifier and conditioning circuit will guarantee 0-5 volts. As this is just for my experimentation, I can live with that.



I love my wiring pencil, but I think I've said that before!



Notes

I had a lot of trouble with the software TX. My code was fine, but after much frustration I found the sink-driver of the PB0 pin in the particular tiny13 I was using was dead! When I added a LED to see what was going on it incidentally implemented a pull-down and things starting working fine. Switching over to PB1 cured the problems, but ideally I should replace the chip with one I haven't accidentally cooked in previous experiments.

There might be enough space left to implement software RX and have commanded sampling, rate and channel setting, etc. A larger device could easily do this, the current code is about 800 bytes. The full state machine for a software USART might not leave a lot remaining for the application in the tiny13; parsing textual commands is probably out.

Linux makes it really easy to use the device. After issuing stty against the appropriate /dev/ttySx device to configure the port you can simply cat data from the device node into a file. I doubt I'll write a client-side utility, as this interface is fine for my purposes and can be scripted up as needed. The data format interfaces well with GNUplot (somewhat by design), and is trivial to manipulate with awk or other languages. I used canonical text (CRLF) for "Microsoft compatibility" but the CR is easily removed with the appropriate stty option (igncr) while using from Linux.

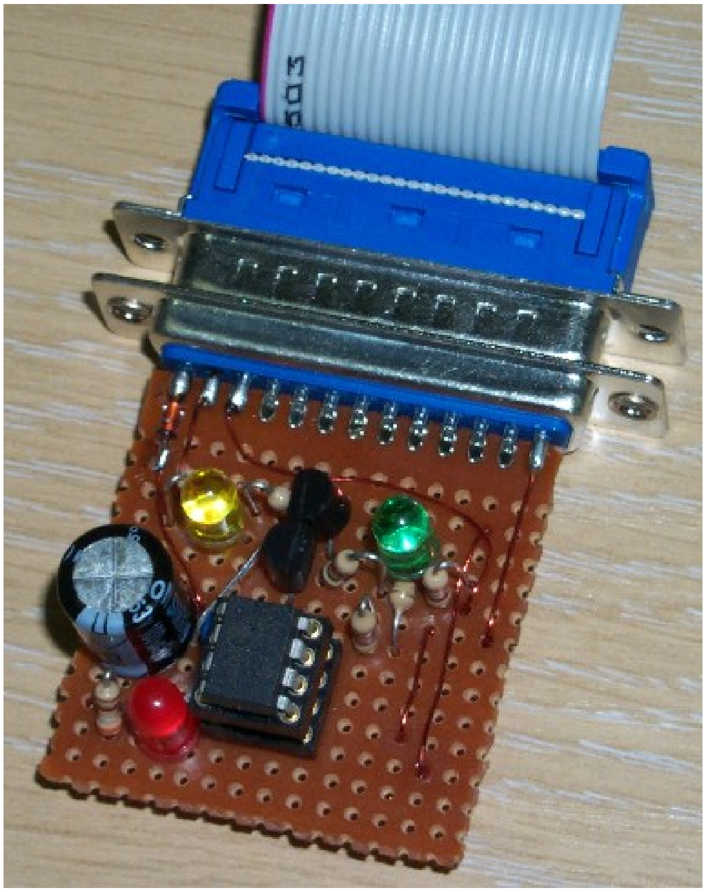
2 comments.

Attachments

title	type	size
The ATtiny13 C-code For RS-232 Linked ADC Read-out	application/gzip	5.326 kbytes

Serial EEPROM Programmer

2003-04-18



Here is a simple serial (I2C) EEPROM programmer for the PC parallel port. I built it to program 24XX devices, but it can, in principle at least, talk to any I2C device with a suitable adapter or fly-lead, it implements a complete I2C bus interface.

The original prototype and control software was developed against a 24LC16B device, but has since been extended and tested against the 24LCX range with X in { 08, 16, 21, 32, 64, 128, 256 }. It should work fine with other 24X I2C EEPROM devices, perhaps with slight changes to the addressing logic and sizing for larger devices like the 24LC512 (and 24LC1024 when it becomes available). Adding an extra device is generally just a matter of adding an extra struct near the top of 24xx.c and recompiling.

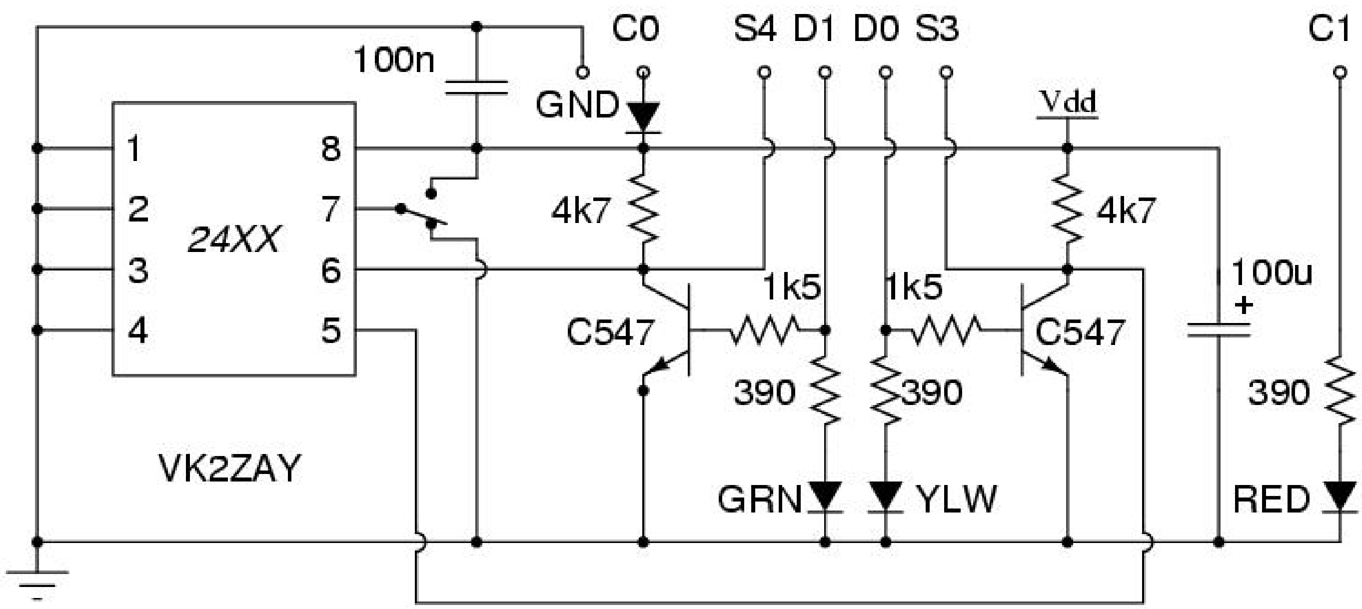
One exception might be the power supply. The 24LC16B and other similar chips pull just a little more than 3 mA when writing to power the internal programming voltage generator (less when reading, and virtually nothing in standby). The programmer is port powered but the parallel port outputs are specified to source only 3.5 mA. That is cutting it a bit fine, but in practice it has worked perfectly on several different PC parallel ports.

Power is sourced from the C0 bit, on some weird parallel ports this may be open collector rather than being capable of sourcing current. If yours is one of them, or you suffer other power problems, you can try pulling power from D2-D7 and C2-C3 with extra diodes, they are all pulled up by the software. If all else fails, supply an external 5 V supply. The diodes will protect the port if external power is supplied, especially if you intend to use the programmer as a generic I2C interface.

Note the switch/jumper in the diagram that allows selection of the state of the /WP signal on most devices. This was added after support for the 24LC21A was requested by Miika Ahdesmäki. The 24LC21A's /VCLK signal has the opposite sense to the usual /WP, as do several others designed for plug-n-play data service. The driver was also modified to pre-clock it as per the requirements in its datasheet to get it into the bi-directional operation mode.

A bi-directional parallel port is not required as the SDA and SCL lines are read through the Error and Paper-Out status bits (S3 and S4). The C1 bit drives a power indicating red LED (or a "don't remove chip" warning if you prefer). The D0 and D1 lines drive the pull-down of SDA and SCL, they have a yellow and green LED to display their states. (The state of the pull-down drive, not SDA and SCL themselves! You may wish to add two more transistors to drive the LEDs from the bus state instead, making them more useful.)

Parallel Port 8-pin i2c EEPROM Programmer



Signal	D25 Pin
D0	2
D1	3
S3	15
S4	13
C0	1
C1	14
GND	18-25

Supply is sourced from the Strobe (C0) pin.
This worked fine for the low power EEPROMs
I tested the device with. Add diodes from spare
pins, or an external supply, if the current sourced
from the port is insufficient.

Measure the rail voltage during writes (when the chip will be pulling more than 3 mA. It should not be below 4.8 V if the port is supplying sufficient current.

You can download my Linux user space programmer drivers. They call ioperm() to establish access to the I/O space for the parallel port so they must be run as root, or setuid root. Currently the I/O base is hardcoded for the 1st parallel port at 0x378. The code is interactive, entering '?' at the prompt will give you a list of options:

```
Commands:
        q               Quit
        ?               This usage message
        d               Dump EEPROM, as hex
        D <start> <len> Dump EEPROM, as hex
        f <value>       Erase EEPROM, filling with value
        r <filename>    Dump EEPROM into raw binary file
        w <filename>    Program EEPROM from raw binary file
        t <type>        Set EEPROM device type (as 24C<type>)
        p <delay>       Set delay between I2C transitions (for slower devices)
```

It is fairly primitive right now, it only supports raw binary input and output files, but I intend to add support all the common hex-file formats. It already has the option to dump the data pretty-printed in hex for manual inspection, and can fill the device with a specified byte to clear it or test it for bit failures near its end of life.

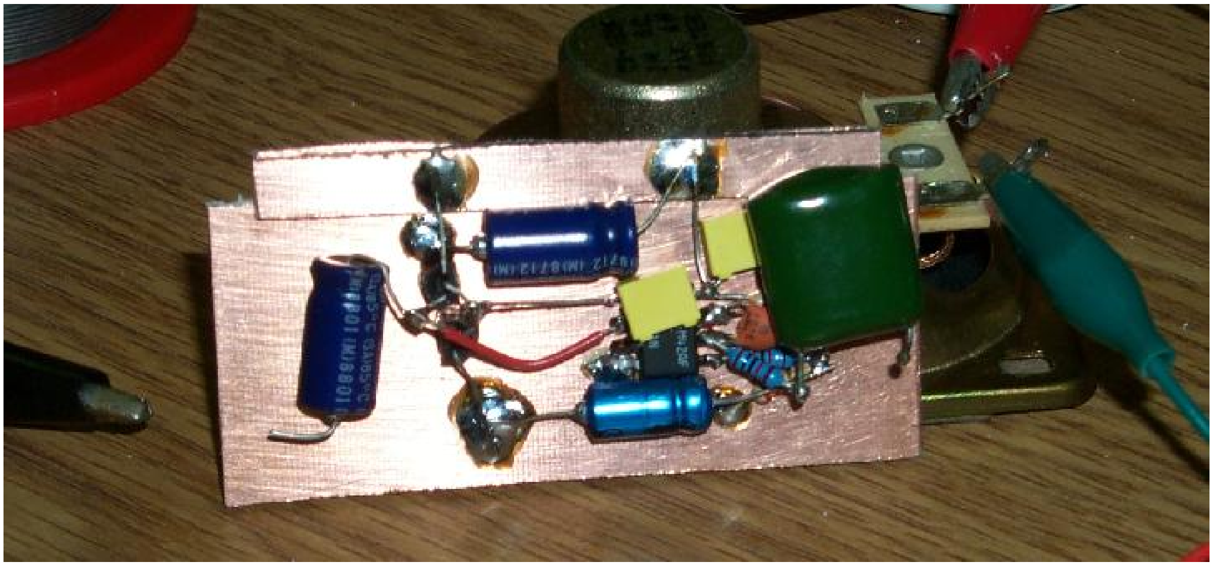
It would not be very challenging to make this code portable to Win32 console, just replace the inb/outb() and ioperm() calls. All else should port directly. This is true for all remotely POSIX systems, as long as they have some facility to allow user space programs to invoke I/O instructions.

10 comments.

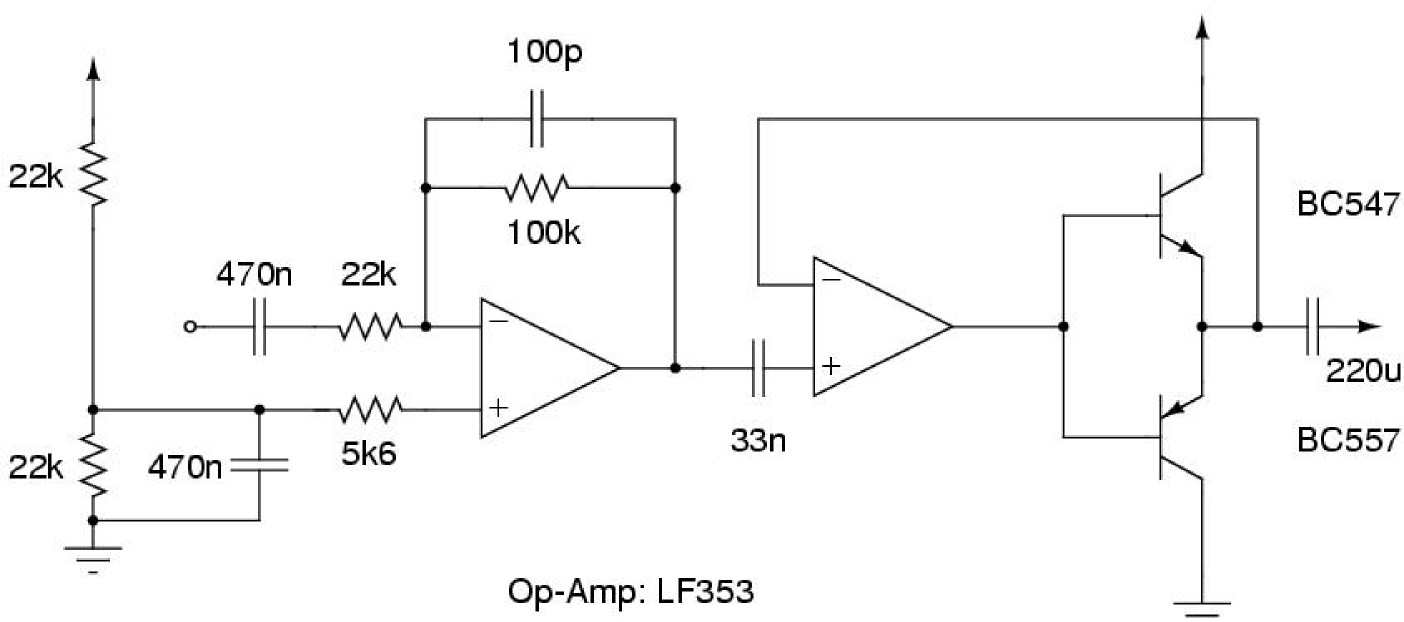
Simple AF Amplifier

2001-09-24

I use this device as a desktop AF amp. Just the ticket for listening to signals from new equipment as it is built, or for removing the headphone leash from some of the lower power equipment I've built.



The output power is limited by the final devices, just two garden variety BC5X7 units in push-pull. The LF353 was chosen because it was the first I grabbed, and it wasn't a bad choice, I like JFET opamps much more than bipolar ones. The first op-amp is used as a unity gain current amplifier, the 100% voltage feedback pretty much eliminates crossover distortion. The remaining op-amp is used as a pre-amplifier and low pass filter, the roll-off is much higher than the response of the speaker, which was found in an old TV dumped outside my office.



These values in the diagram are from memory, and squinting at the images. They may be a bit off. Nothing it too critical, just be careful of too much gain in the first op-amp, it will oscillate. I haven't shown the decoupling caps in the diagram either, the working model has a 33n from pin 8 to the ground plane, and a 220u across the rails. If you use a bipolar op-amp instead of the LF353 the 33n coupling cap will need to be increased (a lot). Alternatively use DC coupling as I have in a few other implementations.

The casing is a large-size project box, the 'old style' ones from Jaycar before their great new line of CAD boxes with the drilling helpers on the inside of the lid. (the new boxes are really, really good, beats DSEs hands down) This older box however has a weird surface layer, it kind of peeled when I drilled it for the speaker grill, and part melted making for a thoroughly ugly result.

Feature wise, it is functional though. The front-panel has a volume knob and power switch, with a choice of BNC or RCA signal input plugs. There is an internal 6v battery pack (4x AA alkaline cells), plus an external DC plug-pack socket which disconnects the batteries on connection.

1 comment.

Attachments

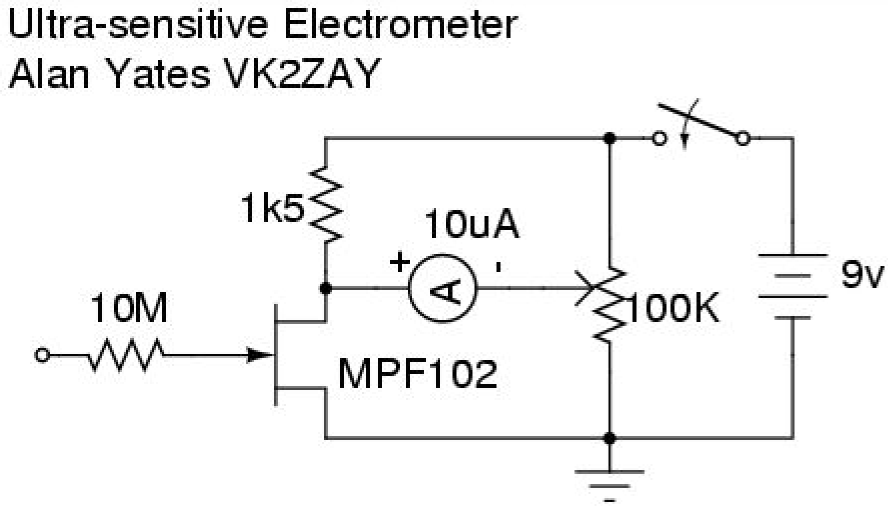
title	type	size
circuit postscript source	application/postscript	11.914 kbytes

Simple Electrometer

2002-11-16

A trivial JFET electrometer isn't a new idea, there are millions of designs for them out on the Internet, this is just yet another. This one is slightly unique in that it is a bridge configuration that makes it ultra-sensitive, much more so than a gold-leaf electroscope, but less than a vacuum tube or electrometer grade FET device.

When the unit is first switched on the pot is adjusted to give a half-scale reading on the meter. You may wish to have a centre-neutral nulling meter, but I only had the conventional meter in the junk box. I used a 10uA FSD meter which makes the electrometer fantastically sensitive, probably too sensitive at times, and difficult to null. A plastic pen rubbed against your hair slams the needle at more than 2 feet away.



A selection of shunts or another pot across the meter would enable sensitivity adjustment. The 10M gate resistor is not strictly needed, but helps to protect the FET gate. Changing the value of the pot would effect the sensitivity and may be required if different FSD current meters are used. The 10uA FSD meter is the most sensitive DSE carry. The PCB material the device is built on is copper clad on both sides, this forms the ground connection and gives the electrometer a ground reference. Both sides are interconnected for good grounding.

You can charge the gate by induction slightly, which may give more range in both polarities. If you do charge the gate it will slowing leak away, but this takes a fair while. If you accidentally touch the gate with a charged object and excessively charge it slamming the needle, just touch one finger to the ground plane and another to the electrode to return the gate to a relatively neutral state.

The gate is sensitive enough to sense the electric field of a 9v battery or charged capacitor waved near the electrode. A good demonstration is to take a few nano capacitor with long leads, preferably axial, short it to discharge it completely. Wave both leads near the terminal and little deflection should be observed, just the usual effect of your body near the electrode. Now hold it by one lead, touch the ground plane of the electrometer with your other hand and the other lead of the capacitor to the +ve terminal of the electrometer's 9v battery for a second or so. Now remove it and holding it by one lead approach the electrometer electrode with the other capacitor lead, the needle should deflect a bit in one direction. Next carefully let go of the lead you are holding, say by taking hold of its body encapsulation with your other hand, then take hold of the other lead and again approach the electrometer electrode, it should deflect in the opposite direction. Now hold both leads to discharge the capacitor and try each end again to confirm its discharge.

It is quite amazing to watch it respond to you scuffing your feet on carpet while standing a meter or so away. My coke can Van de Graaff Generator slams the needle from across the room. It will respond to the difference between you touching the floor with your feet while sitting and not touching it, waving your arms around, or approaching the device and taking a step back. If you have a suitable UV light or other ionizing radiation source you can watch it discharge a charged object near the electrode. A thoriated gas lighting mantel discharges a pen cap in a few minutes.

Leave a comment on this article.

Solderability of Enamelled Copper Wire

2009-02-16

Kevin asked about the solderability of the wire I had used in the wiring pencil. I picked the wire I had in stock that was subjectively the was the right gauge and the easiest to solder based on past experience. I hadn't however made detailed tests, so this quick experiment was undertaken to detail the performance of the particular brands I had in stock.

I just happen to have a wide variety of gauges and brands of wire in stock, collected over the years from various suppliers. The supplies may no longer carry the particular wire I tested, or carry something different identified by the same catalogue number, so this data is only really for my benefit, but the experiment is easy to perform for yourself.

I generally find enamelled copper wire is much easier to tin from a cut end. Submerging the cut end in a puddle of solder on the tip of the iron will rapidly burn back the varnish except for especially refractory varnishes, of which I only have a few samples, mostly on quite heavy gauge wire. Tinning in the middle of an unbroken length is generally quite difficult, at normal soldering temperature, except for very fine gauge wires.

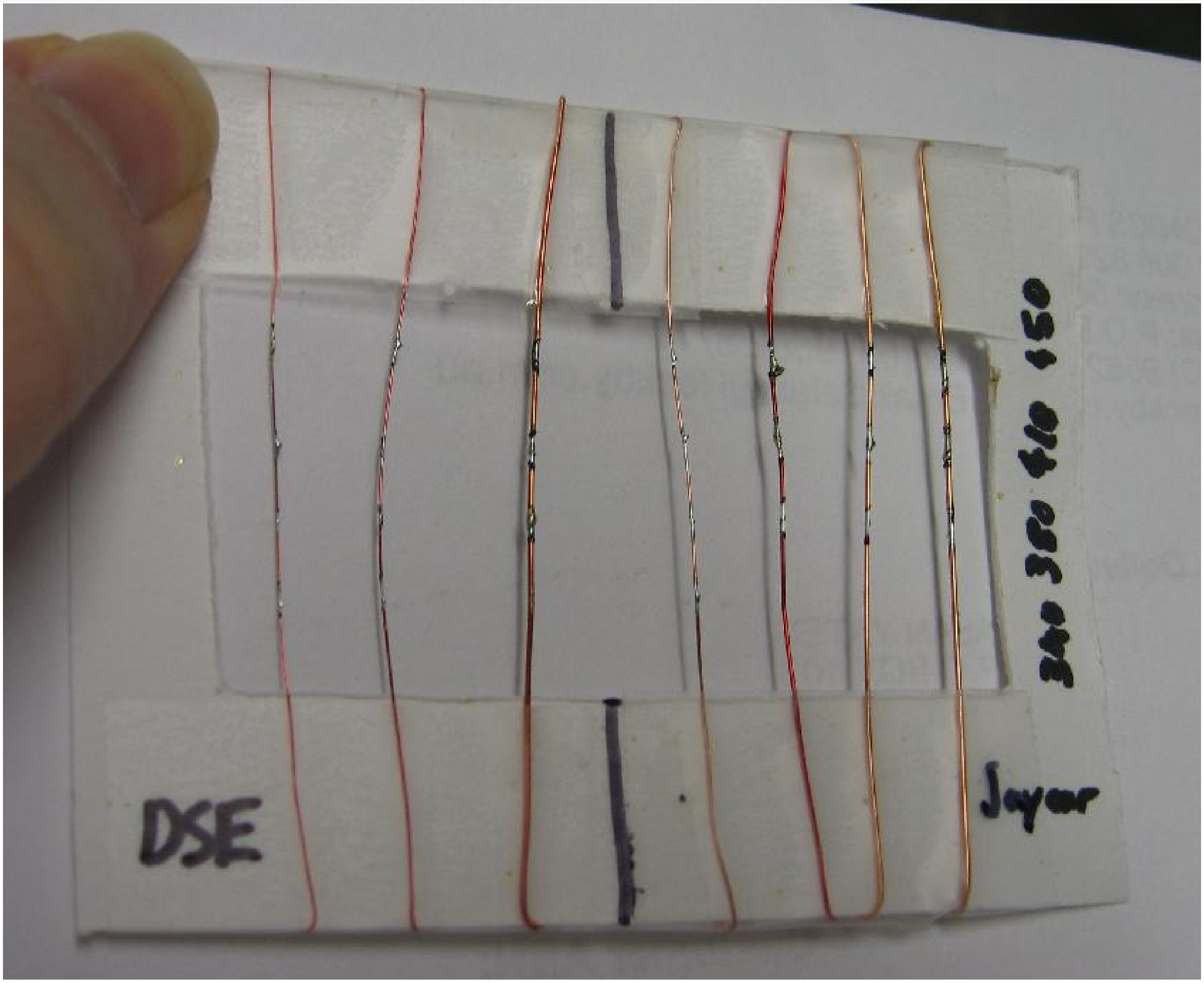
I have a cheap DSE sourced temperature controlled soldering station (catalogue number T-1976) which I purchased last year after my previous unit (also DSE sourced, the more expensive T-2200) was no longer supported by DSE for spares and I was in need of a new element. The unit is adjustable from 250 - 450 °C. I normally run at 340 °C, so I picked four test temperatures, starting with 340 °C and going right up the the units limit of 450 °C. Temperatures below 340 °C were not investigated.

Samples of wire were taped to a cardboard frame and tinning attempted at each of the four temperatures. The heat effected zones may have overlapped, especially for the thicker more conductive gauges, but lower temperatures were attempted first, progressing to higher ones. The tinning was attempted to a maximum of 20 seconds per test. Wires up to 500 um only were tested.

Supplier	Catalogue Number	Gauge	Colour	Solderability				Comments
				340 °C	380 °C	410 °C	450 °C	
DSE	W-3136	125 um	Red	Easy	Easy	Easy	Easy	By far the easiest wire to tin
DSE	W-3132	200 um	Red	Easy	Easy	Easy	Easy	Quite similar to the 125 um wire, takes slightly longer to tin, but otherwise very easy to use and mechanically

DSE	W-3126	400 um	Amber	No	Hard	OK	Poor	Quite hard to tin at low temperatures. Lots of burnt material at higher ones.
Jaycar	WW4012	250 um	Amber	Easy	Easy	Easy	Easy	In most ways identical to the 200 um DSE wire, just a different colour and slightly thicker gauge.
Jaycar	WW4013	300 um	Red	No	Poor	OK	OK	Takes a long time to burn through and tin. Lots of heat works eventually, fair amount of burnt junk results.
Jaycar	WW4014	400 um	Amber	No	Poor	OK	Poor	Around 410 °C seemed optimal for this wire, producing less burnt material than higher temperatures, but being hard to tin much below this. I found this result a little surprising.
Jaycar	WW4016	500 um	Amber	No	Hard	Poor	OK	Needs lots of heat, not too bad otherwise.
Hendricks QRP Kits	NA	321 um (#28)	Red	Fair	OK	Easy	OK	"Thermaleze" wire. Tins with rubbing to get it started at the lowest temperature. Higher temperatures tin easier, but very high temperatures start to produce more burnt material.
Hendricks QRP Kits	NA	321 um (#28)	Green	Fair	OK	Easy	OK	Same as the Red except or the colour.
W8DIZ "The Toroid King"	NA	255 um (#30)	Red/Green	No	Fair	OK	OK	This is a twisted pair of red and green wires, intended for easy construction of bifilar RF transformers. Both colours behave the same. Tins with rubbing eventually, but not at the lowest temperature. Higher temperatures tin easier. Somewhat difficult to tin from a cut end at the lowest temperature. No burnt material at high temperatures, but the enamel colour fades in the heat effected region, appears to thin out and melt away from the heat.
Unknown	NA	400 um	Dark Amber	No	No	OK	OK	Sourced from Wyong Field Day 2009. Needs lots of neat to tin. Was the only material that didn't tin eventually at 380 °C.
Unknown	NA	250 um	Light Amber	No	OK	OK	Poor	Sourced from Wyong Field Day 2009. Fairly typical of the harder to tin wires. Burnt material at high temperatures.

In general the results indicate thinner gauges are easier to tin. All wires tested tin from a cut end at the lowest temperature, but may take quite some time and effort/rubbing. All wires will tin mid-wire eventually at 380 °C, but some can take quite a long time and require rubbing back and forth with the iron to start penetration of the enamel. At 410 °C and above all wires tin pretty easily. Higher temperatures are more robust and quicker to tin, but also tend to produce more blackening and slaggy solder.



Wires that tin only with difficulty tend to produce a blackened region near the edge of the enamel layer which appears to be a mixture of burnt enamel and rosin flux. The blackening also seems correlated with decreasing quality of the solder. Wire that really needed a lot of cooking produces very slaggy solder that ideally would be removed and replaced with fresh material to make a nice joint.

The smell of the hardier enamel burning is quite different to that of the easily tinned material. There is a fair variety of enamel chemistries available, but I am unsure which correspond to the easiest tinning wires as the wire is uncharacterised as to its particular enamel chemistry. At least here in Australia, unless you order directly from a wire supplier, you seem to get almost random material. In particular the same type of spools are used for different kinds of wire, probably because of rebranding and splitting of bulk lots by the retailers. Some material purchased years apart, but of the same gauge, colour and brand has different enamel. This will no doubt frustrate attempts to use the data above.

One thing I didn't test which might be of more practical value is tinning when twisted around an IC socket pin in contact with PCB pads. This is the ultimate fate of the wire used in the wiring pencil, so good performance there is highly desirable. The two easiest to tin materials also happen to be those I chose for the wiring pencil, and I know that in practice they work quite well in that application. Unfortunately they are also the oldest sourced and perhaps are no longer consistent with what is currently offered by Dick Smith.

4 comments.

Parent article: Wiring Pencil.

Sports Ears Broadcast Receivers

2010-04-24

This Saturday I went to see the Sydney Swans slaughter the West Coast Eagles at the Sydney Cricket Ground. Murray Tregonning & Associates has been providing the Sports Ears stadium narrow casting service and associated receivers for other football codes for some time now, but this week was the first time they have offered it at AFL games in Sydney. The general idea is to broadcast the game officials chatter to listeners present in the stadium. My partner is a huge AFL fan and just had to partake in the new service, so she parted with $45 of her hard earned cash for one of their receivers at the game. I instead took my Yaesu VR-500 (a considerably more expensive device) with me to find the transmission and study the system in more detail.

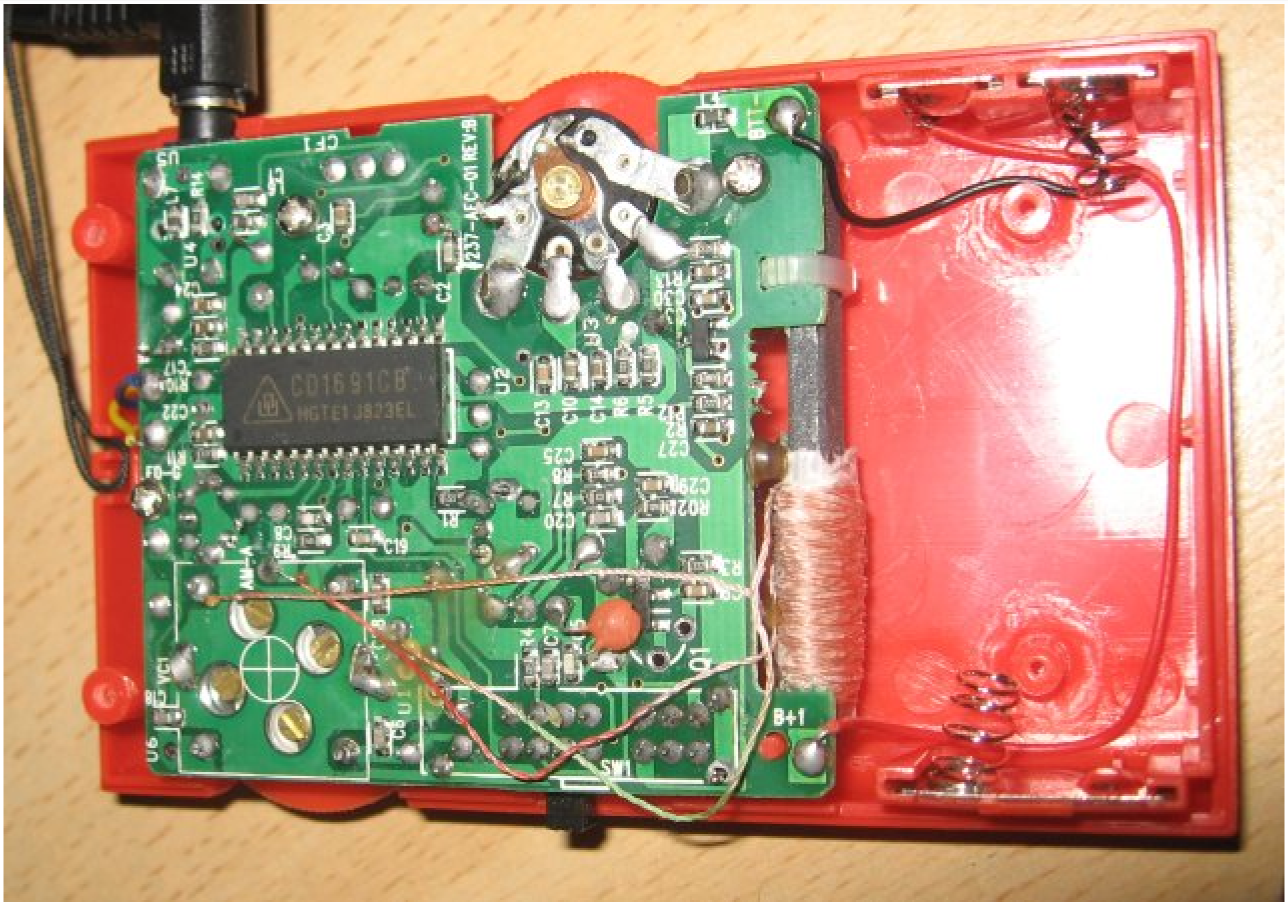
The Magic Frequency

It took only a few minutes to locate the appropriate frequency. The transmission is wide-band FM at 70.2 MHz. The signal strength is reasonable throughout the stadium, probably several watts of transmitter power located locally. Polarisation is difficult to determine with all the scattering of the structure of the stands and people's bodies. Multi-pathing can at times cause deep fading as people move about in proximity, but this is not particular to the system, just a natural consequence of RF communication at this wavelength - FM broadcast band reception suffers similarly.

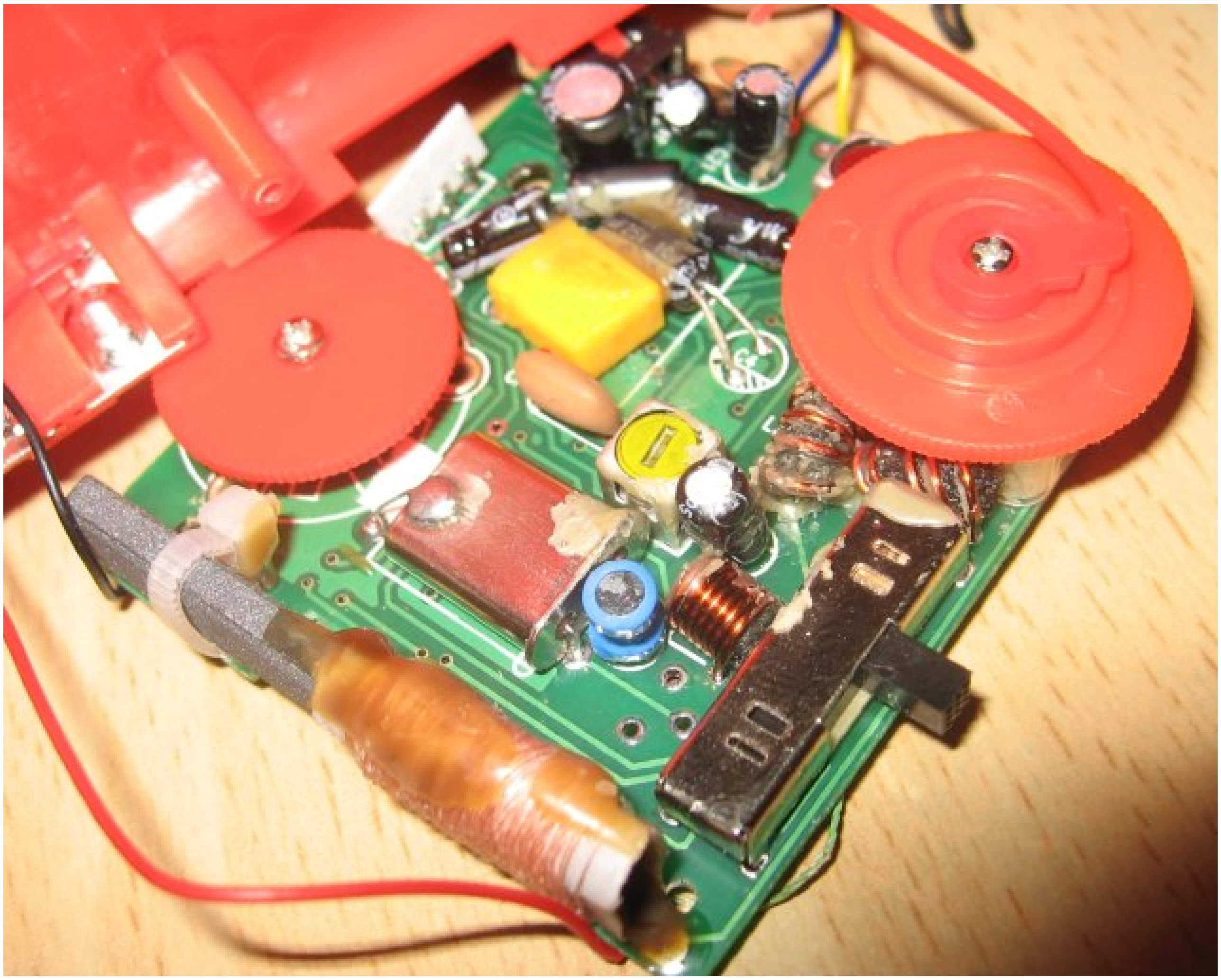
The Sports Ears® Receiver

The AFL Sports Ears receiver itself is a fairly conventional AM/FM broadcast receiver with a 3rd "UMPS" position on the band switch. In the UMPS position the local oscillator is fixed-tuned and receives the 70.2 MHz transmission regardless of the tuning dial position. The AM and FM positions operate normally, tuning 540-1600 kHz and 88-108 MHz respectively. The FM reception is monophonic in either UMPS or FM.

Inside the plastic enclosure is a small hybrid through-hole and SMD board implementing the receiver. The CD1691CB features prominently - a single largish SMD-package AM/FM broadcast receiver and AF power amplifier chip. The AM and FM circuits are very conventional, almost the reference design in the datasheet. The UMPS channel utilises a crystal locked local oscillator, operating at 59.5 MHz for low-side injection (10.7 MHz IF with your typical ceramic filters and quadrature coil).



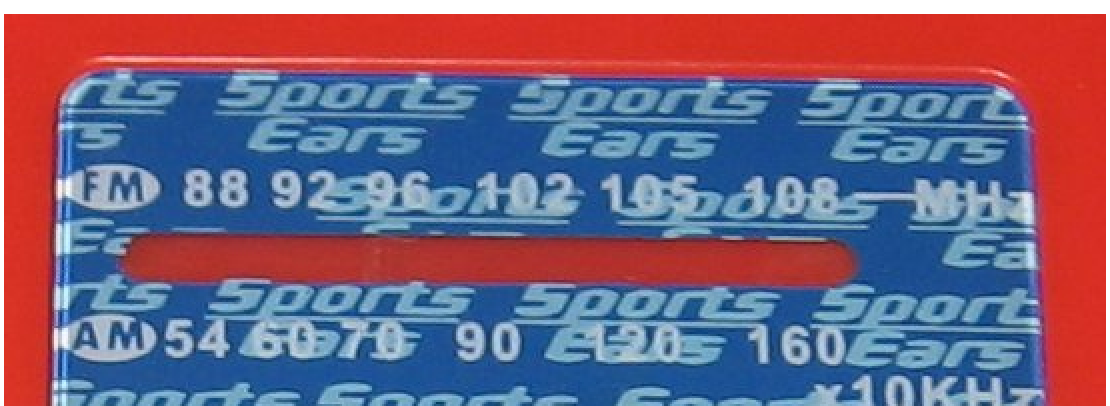
The UMPS crystal is in HC-49/U format, and is completely unmarked - I have no idea if this is an attempt to hide its frequency or simply the result of a custom-manufacturing run. The crystal is one of the larger components of the receiver, and is mounted on the "back side" of the board, accessing it requires removal of three screws and carefully unthreading the red plastic tuning dial indicator from its track. It is no doubt an overtone crystal, but I did not unsolder it to measure its properties directly.



The local oscillator leakage is easily detected at quite some distance from the receiver - even [my wavemeter] can register the LO energy - but no significant sub-harmonic radiation is detectable.

The image frequency 48.8 MHz is not very suppressed, the image response on the FM broadcast band appears somewhat better, as does its sensitivity, but this was not assessed with much precision. Like most radios of this type the antenna for VHF is the headphone lead and controlling the applied signal is a little challenging without modifying the circuit. On FM and AM the LO injection is high-side (the AM IF in 455 kHz), the choice of low-side injection for UMPS is probably to place the image further from the FM broadcast band. The TV sound carriers for analogue TV channel 2 (69.75 MHz) are quite close to the 70.2 MHz UMPS channel and the receiver's selectivity is barely adequate in strong-signal areas when the narrow-casting signal is absent.

Physically the unit is a nice pocket/palm compatible size. It comes with a lanyard featuring a quick-release connector, and a pair of ear-bud earphones of surprisingly acceptable quality. The earbuds are hard-plastic and come with no textile covering "socks" like some other ear-bud style phones do, in particular I found they can slip out of larger ears easily because of the fairly low friction offered by the hard plastic against skin. On the other end of the anatomy scale, smaller-eared individuals may find them too large for comfort. The earphone socket is a conventional 3.5 mm stereo one and phones of your choice are easily substituted. Sports Ears themselves offer over-the-ear padded headphones as an accessory for $20, I can't comment on their quality. The audio power available from the unit before unacceptable distortion is quite adequate with the headphones supplied, even in the noisy stadium environment.



The AFL unit has one rather annoying feature, the tuning dial pointer is coloured red, as is the dial background, making it almost impossible to see even in good lighting conditions.

I took the opportunity when I had the receiver dismantled to colour the pointer black with a felt-tip marker so as to provide some contrast to the display. This is likely an accidental oversight of rushing the device into production, the red colour scheme of the casing being very similar to the pointer. Other code's units have better contrasting colour schemes. Unlike the higher priced units offered for Rugby, the AFL unit has only one receiver and can not simultaneously offer both the umpire audio and FM or AM broadcast band commentary.

The unit is powered by two AAA-size batteries, user replaceable and supplied in the initial package. Current consumption is about 14 mA on FM and UMPS, and 12 mA on AM, at peak AF output power it can rise by an additional 3-4 mA. I strongly suspect the bulk of the current is being consumed by the 3 mm red LED power indicator light, but I did not disconnect it to make a comparative measurement. The cells provided with my partner's unit are brand-name (Mitsubishi) alkaline. Assuming a capacity of about 1 ampere-hour they should run the receiver for about 65 hours. The unit is marketed as having sufficient battery capacity for the entire AFL season, this is quite accurate assuming it is used only 2-3 hours per game. Having the power LED to indicate the "on" state likely helps prevent accidental battery depletion when not in use, despite undoubtedly using quite a large amount of energy itself.

Value?

Their fine marketing aside, is the Sports Ears product value for money? At $45 it is extremely expensive for what's inside the box. A typical AM/FM broadcast receiver of similar quality would be in the vicinity of $10 retail and quite a bit less in large quantity. The addition of the special event channel reception is clearly a fairly custom feature, and some development has gone into adding this feature to an otherwise widely used general "chassis" (not unlike the hundreds of similar merchandising receivers you can get made in Asia in any number of different packaging).

Some unspecified percentage of the sales of the units are contributed back to the AFL and distributed to the clubs. No doubt this particular marketing point is important to many buyers, but a little too weakly specified for my liking.

The entire market for these devices is based on the transmission being on a frequency outside the usual tuning range of widely available receivers. Special Event FM radio licences are available from ACMA, it would have been just as technically easy to offer the service on an FM broadcast frequency that required no special equipment to receive. This is clearly more about creating a captive market for merchandise than simply providing a "fan-based" adjunct to the at-game experience.

There is of course nothing fundamentally wrong with this approach, it encourages attendance to the games, especially if the game official audio is not provided on other coverage of the event. How popular it will be, especially as knowledge of the choices made in its implementation become public remains to be seen.

Personally I found listening to the umpires very instructive and believe it does add a lot to the experience. I frequently record the pay-TV coverage of the event for later viewing, even when I attend the event live - mainly so I can hear the commentary and umpire audio explaining the decisions that can otherwise be quite perplexing when seen live without the benefit of hearing the calls.

The quality of the audio is quite high. Too high at times perhaps, some gentle souls may find the gasping, swallowing and expectorating sounds a little disturbing, although the pre-game and quarter break advertisement loop (and online marketing) warns about the uncensored nature of the content, especially concerning profanity. Further scanning around during the day suggests the microphones carried by the umpires operate around 225 MHz and likely use a diversity reception system to eliminate fading. Other interesting SCG specific frequencies

are around 499 MHz, although my VR-500 had insufficient selectivity to separate some of the powerful concurrent transmissions in close proximity, especially the camera direction instruction transmissions.

Security Through Obscurity?

A junk-store FM radio costing only a few dollars can be trivially modified by a suitably handy person to receive the 70.2 MHz transmission. No doubt the great majority interested in listening in will just cough-up the $45 for a Sports Ear receiver, despite the fact the transmission is unencrypted and emitted not too far from the FM broadcast band so as to make modification of a conventional receiver quite practical (and economical production of the Sports Ears receivers for that matter).

The controlled market for the receivers is obviously bad for the fans. Especially considering the current pricing point. I can't see how Sports Ears could prevent other agents developing receivers for the frequencies used in AU and NZ. I assume their only protection is the expense of development and barriers to penetration of the market. The market is surely large enough, but no doubt competing receivers would not be sold at the games in the merchandise stalls.

No mention of the frequencies involved are made on the product sites. In fact a search of the ACMA registry of radio communication licences found no entry for 70.2 MHz. Murray Tregonning as an entity is well known to the ACMA, but hold no current licences at all. I could find no entries for anything related to AFL, SCG or Sports Ears either. How the frequency can go unspecified in the ACMA database is unclear.

I have no idea if one of the NRL and ARU frequencies are the same as the AFL one, but it would not surprise me if they were be shared. The Rugby broadcasts clearly use at least two different frequencies. The NZ frequencies are different it seems, probably because of country-specific licensing. In any case a receiver capable of WBFM reception would quickly find them, probably not too far away in the VHF-L band.

Making Your Own Compatible Receiver

Retuning a cheap FM broadcast receiver to cover the 70.2 MHz band is actually very easy. Almost any non-digital tuning FM broadcast receiver will do, but a turn-the-dial rather than push-to-scan receiver is probably a safer bet to try. Simply locate the local oscillator coil and squash its turns together to move the frequency down. In many cases there will be sufficient range of adjustment to do this, otherwise you may need to add additional capacitance across the oscillator coil, a trimmer can be soldered across it and set to place 70.2 somewhere in the range of tuning. You can use the channel 2 TV audio signal as a reference, if you can receive it at the bottom of the tuning range (and perhaps still get the bottom couple of the FM radio stations now at the top-end of the dial), then 70.2 MHz will be just above, quite close to the TV audio.

FM radios designed for the Japanese market are even closer to the frequency in question and need less prodding and poking to get aligned.

Alternatively if you don't feel confident hacking a cheap-store receiver, you can even buy a receiver that covers the frequency in question (and more) for less than the Sports Ears product. Dick Smith for example still carries an TV-audio receiver, catalogue number A-4289 ($29.98 - appears to be a Digitor branded Tecsun). Over the years they have carried a number of similar units, I have an older model which is essentially identical internally, you often see them at garage sales or ham radio trash and treasure days for about $5.

Yet another way to receive the signal is to build a converter that mixes the 70.2 MHz up to something in the FM broadcast band. The region around 100 MHz is empty by design for LIPD devices, like toy radio microphones. It is a simpler matter to build a 30 MHz oscillator and mixer to shift the signal up to 100.2 MHz. In fact I found by experiment that most cheap FM broadcast receivers have such poor front-ends just placing them near a strong 30 MHz signal will cause them to mix up 70.2 MHz to 100.2 MHz internally. A simple overtone (3x 10 MHz xtal) oscillator held near a junk store FM receiver made a test signal at 70.2 MHz easily detectable with the receiver. A packaged 30 MHz TTL oscillator + a battery is an instant converter with a suitably average FM broadcast receiver. (This trick even works on my VR-500 because its LNA is broad as a barn door and fairly weak IP3 wise too.)

Can I Use The "UMPS" Channel Myself?

Well, technically it is very easy to build an FM modulated flea-power transmitter for 70.2 MHz and use your Sports Ears receiver around the house. Just take the typical "FM Microphone", "Wireless Bug" or "Sound Feeder" and retune it to operate at 70.2 MHz. Legally this is probably slightly more illegal than LIPD devices on the FM broadcast band. Obviously taking such a device to the game would be a very dumb idea, but around your home the chances of the signal being seen at any distance are quite small unless you build a good antenna for the transmitter. One wonders why you would bother hacking over a perfectly usable FM broadcast band transmission device, perhaps even capable of high-fidelity stereo transmission in the case of a sound feeder, and locking it down to a fixed-channel, mono uncommon receiver like the Sports Ears. A similar argument might equally apply to Sports Ears in the first place...

Summary

Sports Ears works well. It is fun, pretty much as described in the marketing hype, definitely worth a try if you are attending the games. The implementation method is perhaps a bit morally questionable, especially as the units are arguably overpriced, but the consumer is informed about the proprietary nature of the system and its limitations - the FAQ is quite clear in that respect. The consumer however is not informed that alternatives are available and this was my main motivation for writing this article.

17 comments.

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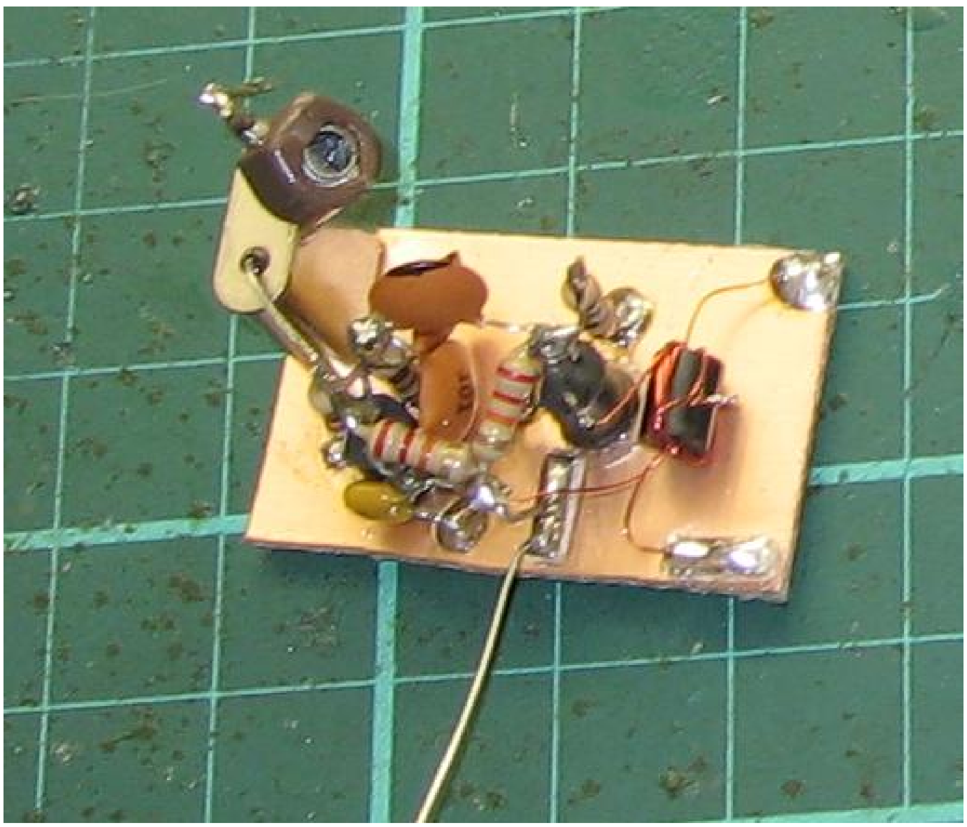
SSB Exciter

2006-11-11

I recently ordered 200 units of 11.98135 MHz crystals from Hy-Q for use in crystal ladder filters. (They were $5/100 in their surplus stock sale section) With the construction of my RF sweeper, I can now make precision filters suitable for SSB and CW transceivers.

Four crystals were selected with a minimum frequency within 50 Hz. The 30p to ground-shorted shift was measured and capacitors calculated for a 2.5 kHz bandwidth. Some fiddling later and a filter with fairly good characteristics was produced. The termination Z was selected to be 150 Ohms and some tests showed it offered pretty good ripple with the particular crystals used.

A crystal oscillator with padding inductor was constructed to generate the carrier, and a diode DBM was made with ferrite beads and 1N4148 diodes.



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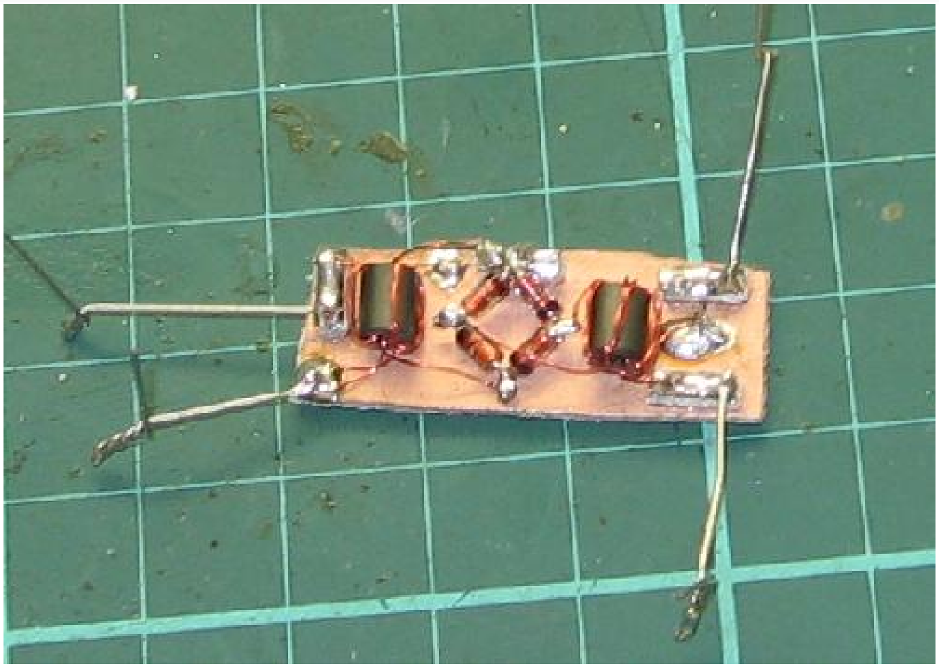
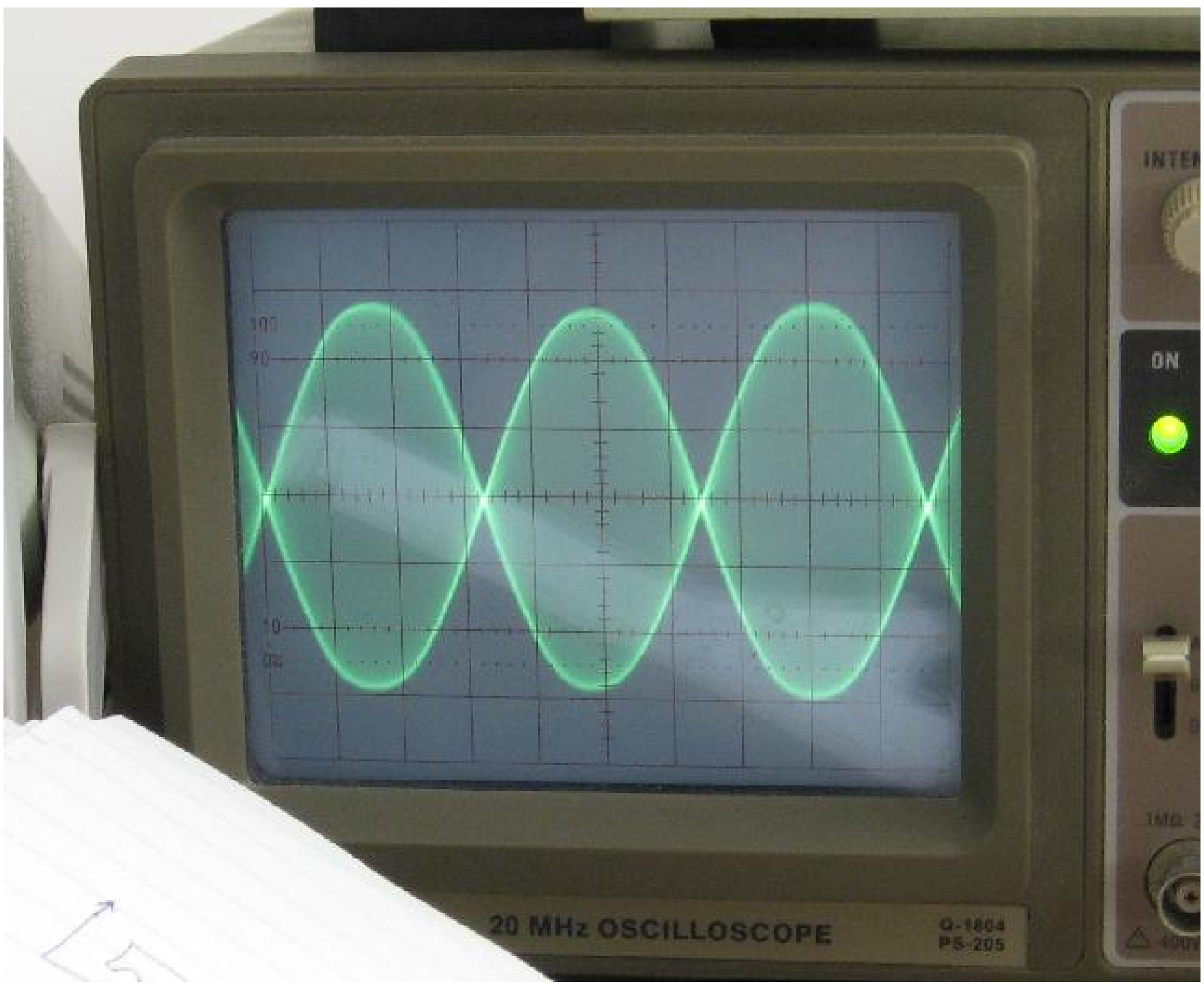
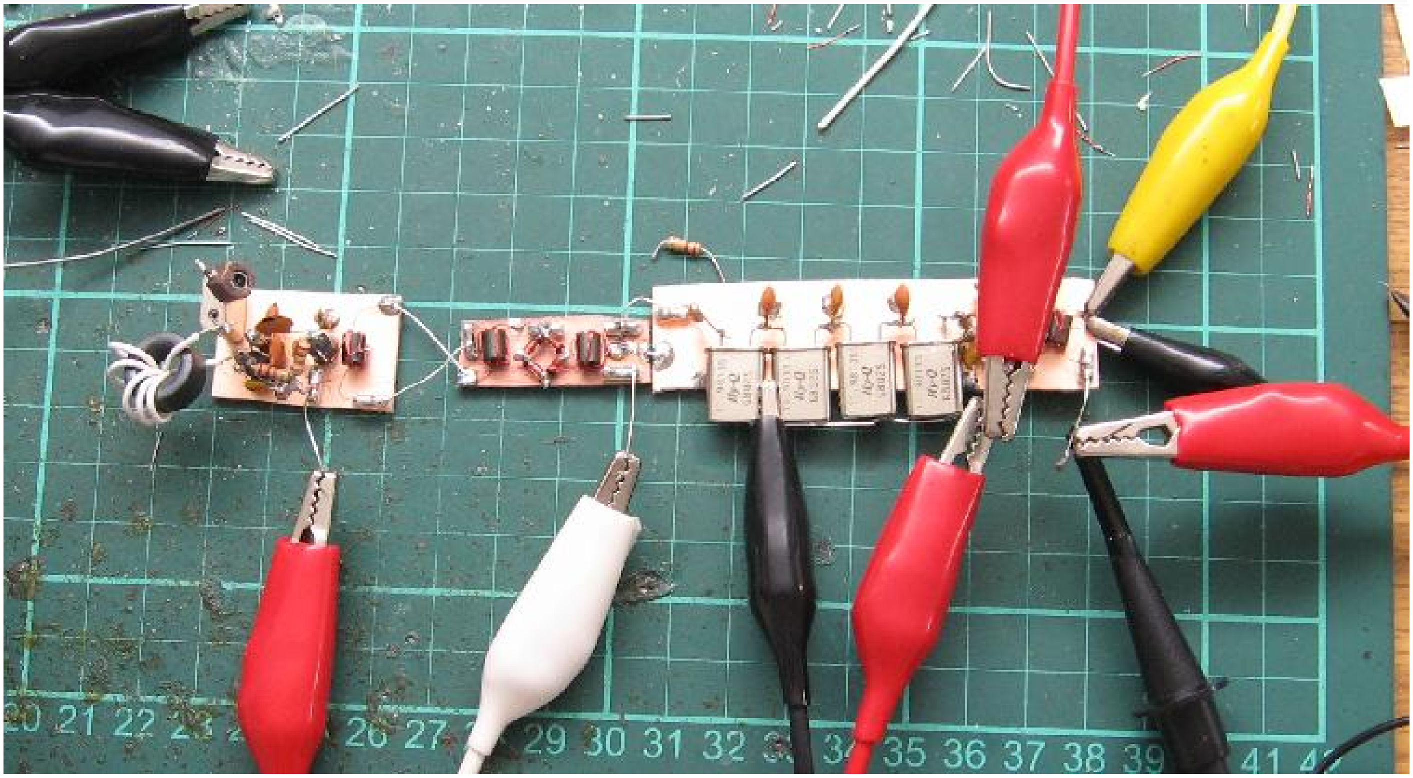
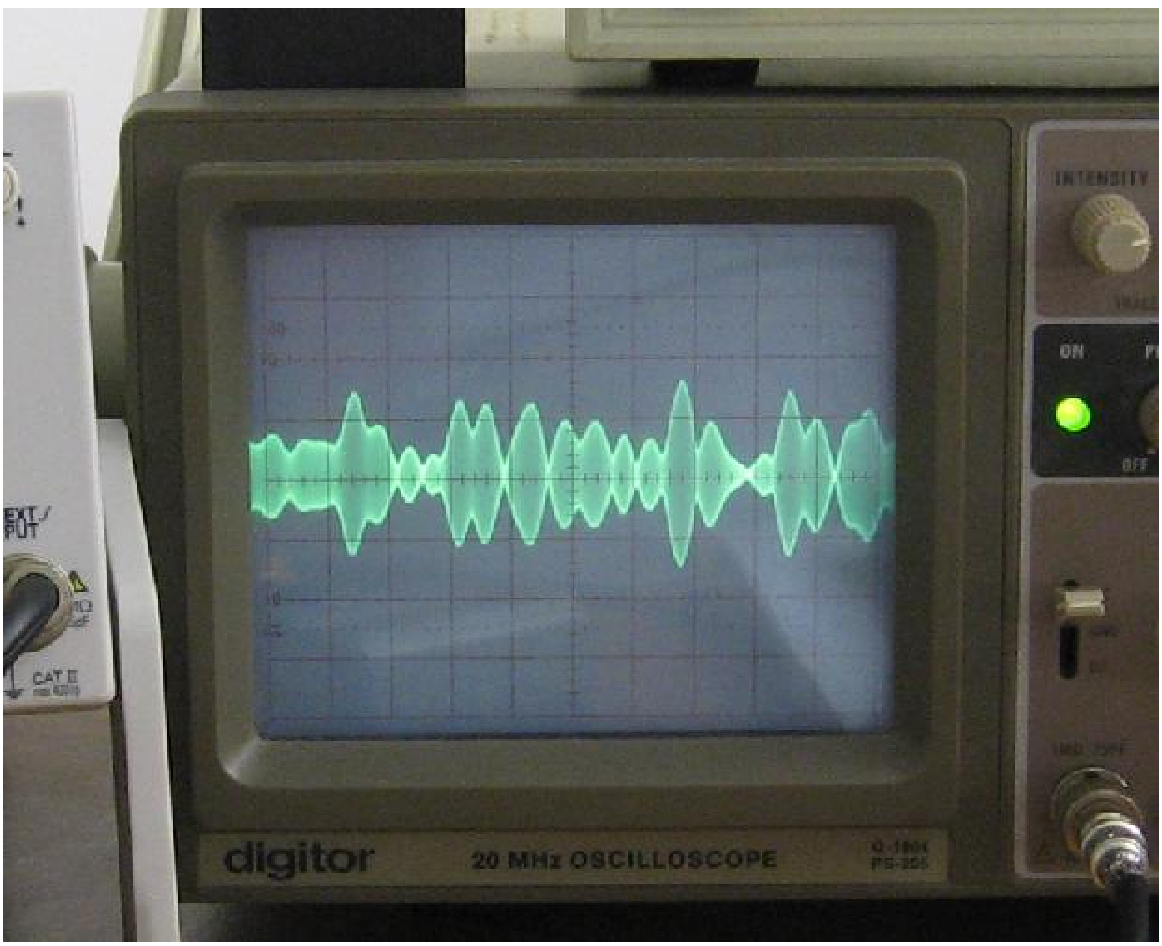


A quick lash-up on the desk proved the carrier oscillator and DBM alone produced a nice DSB signal.



The crystal filter was added with a buffer amplifier after it to compensate for its insertion loss. Some teaking of the carrier frequency later and a very clean LSB signal was produced (LSB is easier because of the filter shape). I used an AM radio as a signal source.





Next step is to make an microphone amplifier with AGC and then start thinking about switching the modules around to enable RX as well (I've already purchased DPDT mini-relays to do this). Then it is a relatively simple matter of building transverter-style circuits for the bands of choice. I think I'll investigate switchable carrier oscillator frequencies to enable LSB/USB selection. This will also give me more choices of LO injection frequencies.

40 metres will probably be my first band, I have a dipole for it already, and it is fairly open at the moment despite the solar cycle being at rock bottom.

Carrier suppression could be better, the crystal filter knocks it down 3-6 dB, and it is already about 16 dB down. I may replace the DBM with a single-balanced modulator having a carrier nulling pot so I can reduce the carrier power as much as possible.

2 comments.

Alan's Lab

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Switching Boost Converter Power Supply

2008-12-28

Building switchmode converters is something I had basically no experience with and only a very casual theoretical understanding of. Some might say it would have been safer and easier to just follow someone else's design, or at least pick one of the thousands of commercial blackbox chips out there... If I did that I wouldn't have taught myself as much about the wonderful mix of disciplines such circuits require knowledge of.

Requirements

First the requirements. My lab is lacking a high-voltage DC variable supply, something capable of say 40-200 volts at a few watts (say 10-20 mA) with current limiting protection. Such a device would enable basic vacuum tube experiments amongst a whole bunch of other uses. I wanted it to run from 12 volts input as I have plenty of such DC supplies and could avoid the dangers associated with low impedance mains work.

Critical Components

After reading some theory and sketching circuit ideas I dug through the junkbox looking for suitable parts; a HV MOSFET, a fast HV diode, a low ESR HV cap, and a suitable storage inductor. Unfortunately the best MOSFET I had Vds-wise was the humble IRF510 which at 100 Volts constrains the boost topology to delivering 112 volts. Diodes I had no problems with, I have a stock of BY229-600s which are very over-spec for the project. Output side filtering caps were looking grim, I wanted 1 uF 400 V or better, but had only 100 V in anything but vanilla electrolytic. I tested one 100 Volt mylar cap to over 300 volts - that will do for initial experiments as my MOSFET limits me to ~100 volts anyway unless I go for a flyback topology - maybe later. The inductor was the final remaining critical part, but pot and E-cores I have aplenty, along with power chokes.

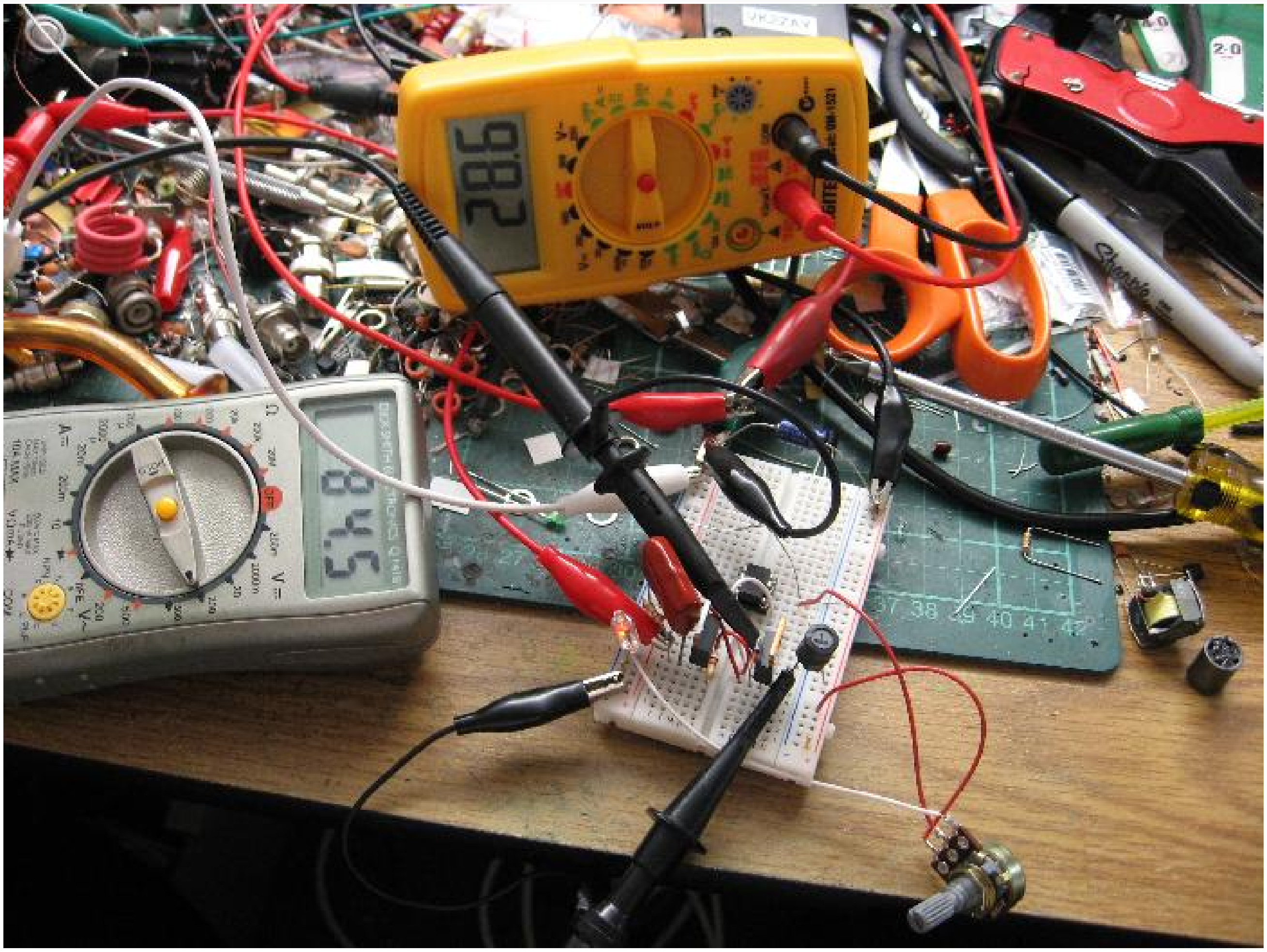
Controller

The controller was originally going to be discrete, but after spending 2 days in LT Spice fiddling I decided to do something completely different for me - use software! I'm fairly well tooled up for using the Atmel ATtiny13 so it seemed logical to use it. The tiny13 has fast-PWM and ADC capability and a 9.6 MHz internal clock, so it can easily handle the job with *far* less parts than any other solution I was looking at.

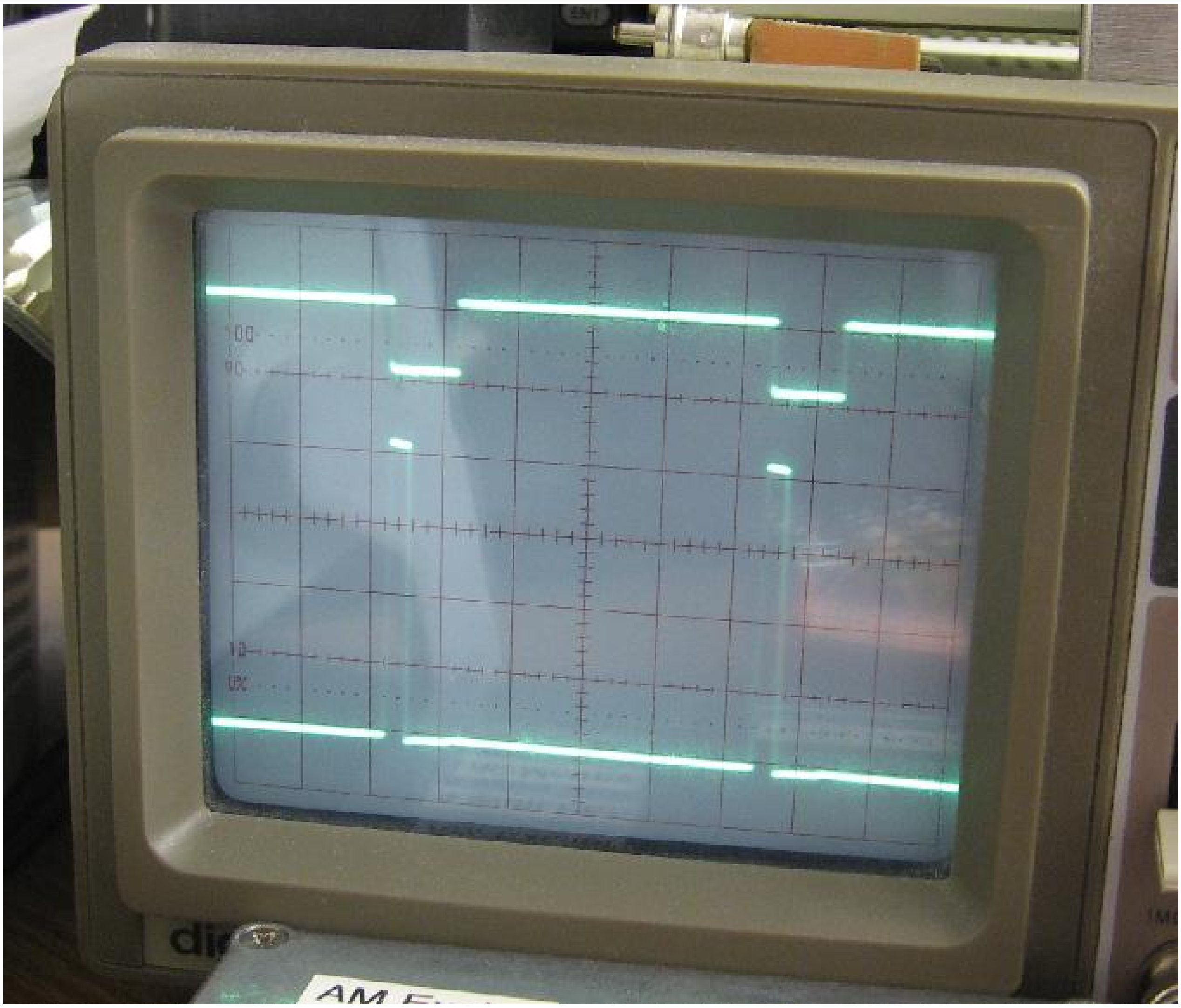
Variable Duty-Cycle Experiments

To begin with I wrote some simple code to allow fiddling with the inductors I had and in general learning about switching boost converters. The code simply sets the PWM output duty cycle to match the ADC conversion reading. This lets you implement a 0-100% duty cycle controller with only the tiny13 and a pot (at a fixed frequency - 37.5 kHz currently). This piece of code is actually quite useful in its own right and can be a speed/power controller for motors, brightness control for lamps, etc. Anything that needs a variable duty cycle.

After some initial tests lighting up LEDs I breadboarded a basic boost converter and tried it out with the variable duty-cycle controller. To my surprise most of the inductors I had "worked" to some degree. Many suffered saturation problems, but the cheapest and most common 1 mH choke I tried worked quite well with a small load, right up to the voltage limit of the IRF510.



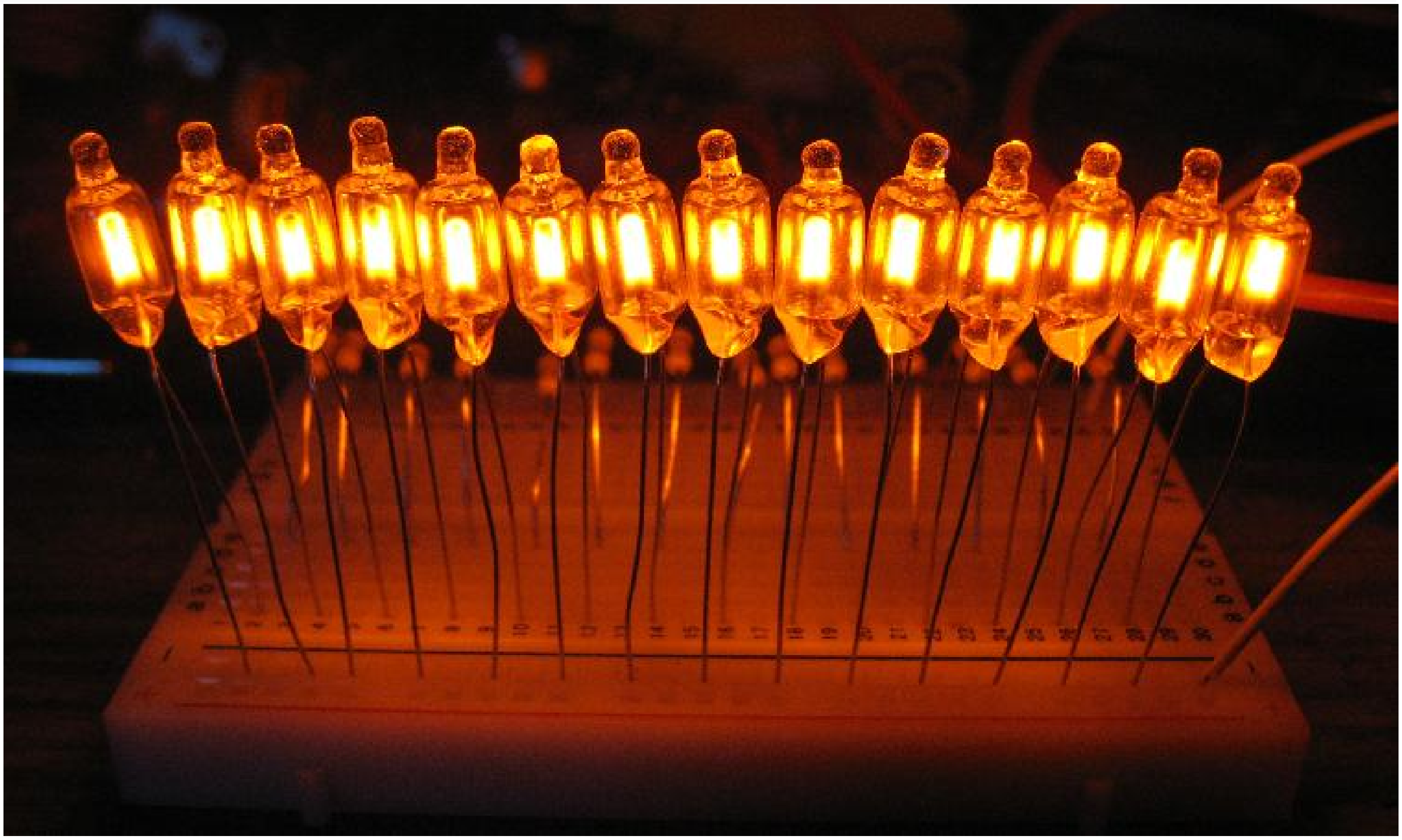
This oscillogram shows a roughly 80% duty-cycle gate drive and the corresponding drain waveform with the HV side under several 10s of mA load. With less loading it was possible to see free-wheeling on the drain after diode cut-off, where the inductor and drain capacitance would ring as an LC circuit. This is harmless, normal and quite expected.



Here is a video of varying the duty cycle. The free-wheeling is observed at low duty drives, eventually continuous mode is entered and voltage increases rapidly, then the inductor saturates and the voltage drops again (with a corresponding rapid rise in input current).

Duty-Cycle Varying Experiment Video
(3.054 Mbytes)

Before long I had a dummy load of neon bulbs glowing brightly and a conversion efficiency of about 74% delivering a few watts. The efficiency isn't too bad considering the relatively large Ron value of the IRF510 and the choke inductor parasitic resistance.



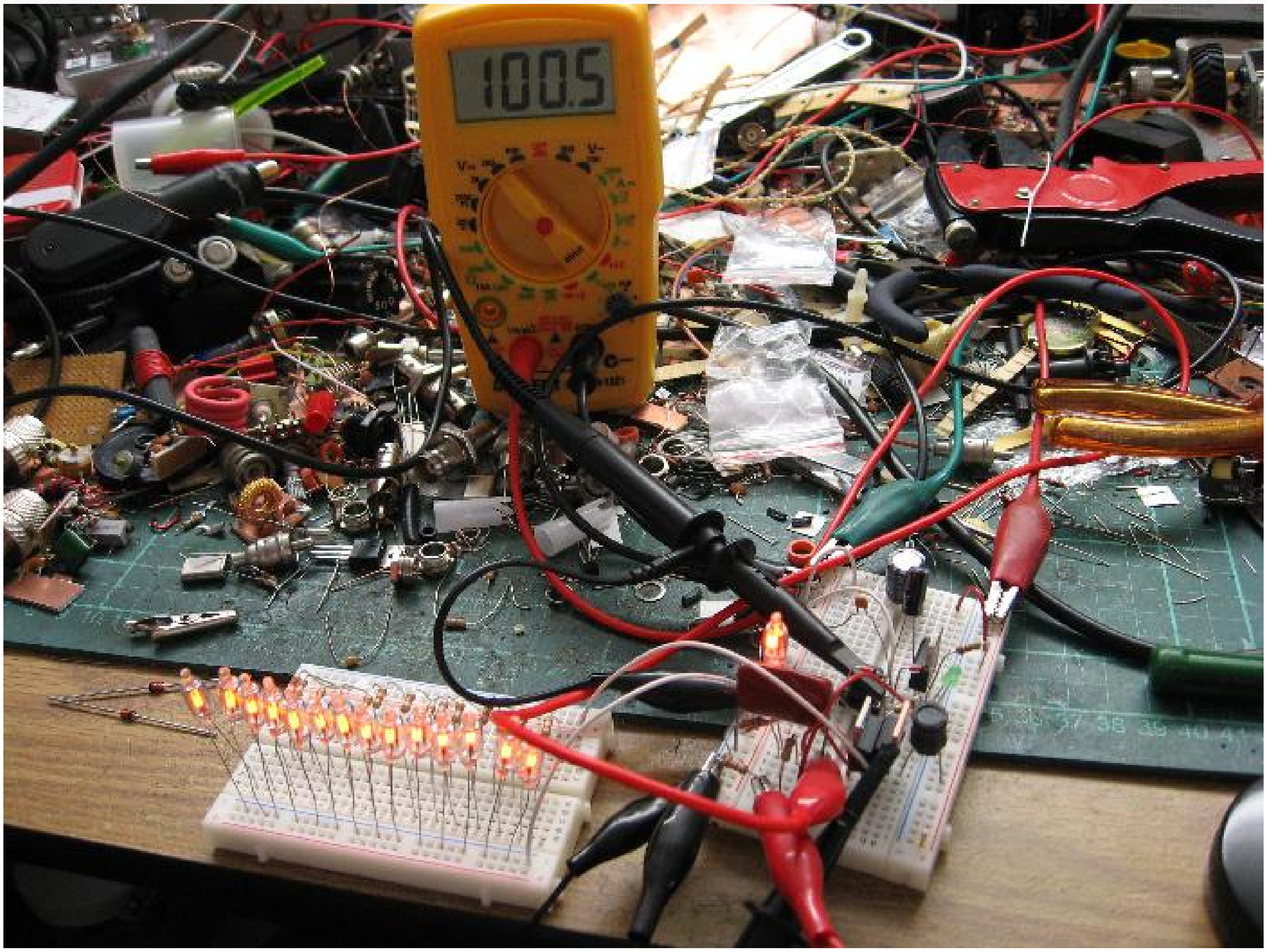
The Inductor

At this point with a 1 mH inductor output current was limited to less than 33 mA, as the 37.5 kHz switching rate only allows the inductor to charge to 282 mA in the 88% duty cycle on-time that corresponds to 100 volts from 12 volts input. Reduction of the inductor value is required to deliver more current, but inductor saturation then becomes more likely - for example a 100 uH inductor can charge to 2.8 Amps in the same time, that's a lot of ampere-turns for most ferrite cores. (And near the drain current limit of the switching transistor).

Time to experiment with gapped cores, and as such I needed an inductor core saturation tester... The test instrument that grew out of this need is quite simple, but I've made it the subject of its own article as it is a useful device in its own right.

Voltage Regulation

Closing the regulation loop was the next step. The controller programming was altered to adjust the duty cycle incrementally based on the ADC input, trying to maintain a value near mid-rail. With simple voltage divider from the HV side feeding the ADC input and some logic to drive a LED when the regulator could no longer retain control (dropout indicator), I had the basics of a working regulating boost converter.



The delay and incremental adjustment affect a low-pass filtering of the control circuit. This seems to work quite well, but I have not investigated its behaviour extensively and have no idea of its stability. The regulation point does limit-cycle even with several bits of hysteresis, the control logic being digital (only 8-bit PWM) and high duty-cycles having a large "gain" in terms of output voltage change with small changes in duty cycle (approaching 100% is an asymptotic limit of voltage approaching infinity - 50% gives you twice the input voltage - during continuous-mode operation anyway). Operation in discontinuous mode with smaller inductors would allow lower duty cycles, but I am unsure if that would lower the loop gain - need to do the maths. Explicit digital filtering in the controller is probably worth investigating.

The controller logic also misbehaves when the inductor saturates or the MOSFET starts avalanching. When this occurs the duty-cycle to output voltage relation stops being monotonically +ve. The regulation will slam hard on against the upper duty-cycle limit. This condition is noted by the drop-out indication LED, but typically results in a large current consumption and would eventually cause damage. Current limiting in the input-side could allow unconditional safety, but it would be nice to detect the condition explicitly and complain because it is a supply hardware problem, not just overload. I have not investigated the lower boundary as much, the Neon bulb pilot light loads the output enough for it to not be a major problem, and the failure condition of a completely lost load is probably not too bad, the duty cycle lower limit can be selected to prevent dangerous voltages being developed.

Protection

Input-side current limiting is the most obvious protection scheme. Almost all failure modes result in large currents being drawn from the input. A simple circuit to detect this and throttle the current might be the conventional transistor pair with an emitter resistor that eventually biases one of the pair on to deprive the other of base current. The voltage drop would hurt efficiency and perhaps a more sophisticated scheme would be in order... For now my bench PSU is giving the overload protection.

Higher voltage MOSFETs and Capacitors are needed to take the experiments further towards a practical supply for the lab requirements. These devices are on-order, but haven't arrived from their suppliers yet. I'll do more work into the protection system and regulator stability after they arrive, and perhaps take a look at a flyback topology to achieve higher efficiency. The flyback topology also prevents input-supply shorts, as would AC coupling of the output. Filtering of the output ripple is another area that needs investigation, perhaps with LC filters although they have problems with load-dumps generating voltage spikes.

2 comments.